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DISEASES OF VEGETABLES

IMPERIAL
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INTRODUCTION

The object of this bulletin is to furnish all who are interested in the growing of vegetables with information which will enable them to identify the more common diseases of vegetables, and to apply intelligently the treatments which experience has proved to be the most effective in each case.

In a bulletin of this nature it has been thought wise to include the bacterial with the fungus and virus diseases, in order to place in the hands of the grower a complete and convenient manual of all the more important diseases of vegetables.

The majority of the diseases of vegetables are what are known as fungus, bacterial and virus diseases. It is important that those having to deal with them should understand fully the cause of such diseases in order that they may apply intelligently remedies for their control.

THE NATURE OF FUNGUS DISEASES

Fungus diseases are caused by plants known as fungi. These plants, unlike ordinary flowering plants, have no green coloring matter (chlorophyll) and are unable, therefore, to manufacture their own food. All their nourishment must be obtained from living plants or animals or the remains of them. Those fungi which derive their nourishment from living plants injure them in various ways, and thus give rise to what are known as fungus diseases.

The bodies of fungi which cause plant diseases are usually extremely small and very simple. They consist of very fine, delicate, thread-like structures (hyphae), some of which become modified and produce reproductive bodies called spores. The spores may be considered similar to the seeds of flowering plants. Sometimes the fungus threads live upon the surface of the plants and obtain their nourishment by sending little suckers (haustoria) into the cells of the plant below. Most frequently, however, they live within the plants, either in, or between the cells. Two kinds of spores are usually produced (1) thin-walled summer spores, which spread the disease during the growing season, and (2) thick-walled resting or winter spores, which serve to carry the disease over the winter. Spores

are scattered by various agencies, such as wind, water and insects. When they come in contact with a suitable host plant, they send out little threads (germ tubes) which enter the plants through the little pores on the leaves (stomata), through the skin or through wounds. Once within the plant, these little threads grow rapidly, drawing their nourishment from the cells of the host plant and set up a diseased condition.

Generally speaking, in combating fungus diseases only methods of prevention are practicable, as once a fungus is within the plant nothing can be done to destroy it. Care should be taken to keep the crops in a healthy growing condition and free from injury by insects. Unthrifty plants and those attacked by insects are more subject to fungus diseases than healthy ones. Rotation of crops should be practised, so that the winter spores left in the soil may not infect the next season's crop. Weeds should be destroyed, as they frequently harbor fungi. Diseased crop refuse should be burned and not thrown on the manure heap. Fresh manure should be avoided, as it frequently contains living spores of parasitic fungi.

Intelligent and thorough spraying with Bordeaux or other fungicides will do much to prevent the spread of fungus diseases. It should be kept in mind, however, that spraying is done not to cure, but to prevent disease. In other words, the object of spraying is to cover the surface of the leaves, fruits or other parts of the plant with a substance which is poisonous to the spores of fungi, and in which they cannot grow and penetrate the plant. Spraying, therefore, in order to be effective, must be timely and thorough. The spray mixture must be on the plant before the spores reach it, and the surface of the leaves, fruit and other parts of the plant must be covered so completely that there is not the smallest space on which a spore can germinate.

THE NATURE OF BACTERIAL DISEASES

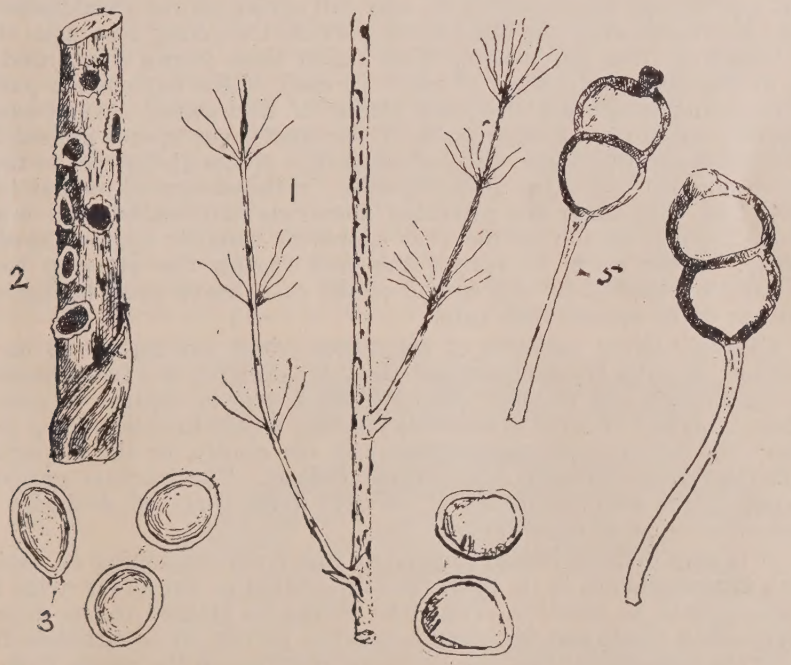
These are caused by bacteria which are single celled minute plants, visible only by the highest magnification of the microscope. In size they vary considerably, but if 25,000 average sized organisms were laid side by side they would measure approximately one inch. They are so simple in structure that all the vital functions such as reproduction, respiration and movement take place within each single cell. They multiply by simply laying down a partition across the cell, and on each side of the partition a new cell is formed from the old half, giving two new daughter cells. This process may take place about every 20 minutes under favourable conditions, and one bacterium may give rise to ten millions or more in 24 hours. They are unlike the higher plants in that they do not possess any green colouring matter (chlorophyll), and for this reason cannot manufacture their own food. Since they cannot manufacture their own food they must live either on dead or decaying organic matter, in which case they are called saprophytes, or on other forms of life such as plants, animals, insects, humans, etc., when they are called parasites. Fortunately most of the thousands of species of bacteria live on dead material and render great service by breaking it down to simple substances which are used by plants as food.

In this bulletin, however, we are dealing only with those forms which live in plants, and of course they must derive their food supply from the plant sap. In this way they cause varying degrees of injury such as leaf spots, blights, wilts, soft rots, and in some instances death of the plant. Their method of entry into the plant varies, and this is discussed in connection with each disease. These bacteria live over on or in the seed, in the soil, in cankers of woody plants and sometimes in the bodies of insects.

They are dispersed by wind, water, insects, on seed, and by the hands and implements of workmen. They enter the plant chiefly through breathing pores (stomata) and wounds made by insects and cultivation.

THE NATURE OF VIRUS DISEASES

These are diseases that are not caused by any fungus, bacterium or any organism that can be seen with a microscope. It is believed that they are caused by a living "something" in the juice of a diseased plant which, for want of a better name, is termed a virus and which, if transferred under certain conditions to a healthy plant, will cause the disease. In many instances the virus may be spread from diseased to healthy plants in any manner that the juice may be carried from one plant to another. Thus many of these virus diseases may be spread from plant to plant on implements, pruning knives and on the hands of workmen. Examples of diseases that may be spread in this way are Cucumber Mosaic, Tomato Mosaic and Tobacco Mosaic. The virus of many of these diseases is spread from diseased to healthy plants by insects. Plant lice or aphids are the chief carriers, though some viruses are spread by other insects. Some of these viruses are carried over from season to season in the seed. This is true of the virus causing Bean and Lettuce Mosaic. Many of these viruses infect a great many kinds of plants belonging to different families, thus the problem of control is greatly complicated.



ASPARAGUS RUST

1. Attacked stem showing spore clusters.
2. Cluster-cup form.
3. Spores from cluster-cup.
4. Spores from summer stage (urediniospores).
5. Resting or winter spores (teliospores).

ASPARAGUS RUST

This disease is often seen in Ontario. Before the advent of varieties of asparagus resistant to rust it frequently caused severe injury to asparagus in many parts of the Province.

Symptoms—There are three distinct stages of this disease. The first is known as the cluster-cup stage or the spring form. It appears on the young shoots shortly after they come above the ground. On these are seen orange-yellow or greenish yellow cup-shaped pustules grouped in oval clusters. This stage of the rust is seldom noticed by asparagus growers. The second or summer stage is the one that is usually first noticed and is called by them the red rust on account of the elongated reddish-brown pustules which are seen breaking through the skin on the stem. The third stage of the disease is seen towards fall or whenever the vitality of the asparagus plants is reduced. It is known as the black rust or winter rust and is characterized by elongated black lines which replace the reddish-brown pustules of the red rust stage.

Cause—The fungus which causes asparagus rust is *Puccinia asparagi* D.C. It produces four kinds of spores which take a direct part in its life history. In the elongated black lines of the black rust or winter rust, thick-walled two-celled dark brown spores are produced. These are known as winter spores (teliospores). They pass the winter on the old asparagus tops and refuse. In the spring they germinate, and each one may produce eight very minute spores which we may call spring spores (basidiospores). These are scattered by the wind about the time the young asparagus shoots are emerging from the ground. They infect these young shoots and give rise to the cluster-cup stage of rust. In each of the cup-shaped pustules on the young shoots are produced chains of thin-walled orange-coloured spores known as cluster-cup spores. These cluster-cup spores are scattered by the wind and infect the stems of asparagus plants giving rise to the red rust or summer rust stage of the disease. In the elongated reddish-brown pustules of this stage are produced numerous thin-walled oval orange-coloured spores known as red rust spores or summer spores (uredinio-spores). These serve to spread the rust during the growing season. Moisture is essential for the spread of the rust, heavy dews having more influence on its spread than rain.

Control—Grow varieties of asparagus which are known to be rust resistant. Martha Washington and Mary Washington are two commercial varieties which are resistant to rust. If a grower desires to secure a resistant variety of asparagus and is not sure where to obtain it, he should consult the agricultural representative in his county, or the Department of Horticulture, Ontario Agricultural College. The various gardeners' journals print advertisements of reliable firms that sell desirable rust resistant strains of asparagus.

It is very difficult indeed to prevent rust from developing on varieties which are susceptible to it. Such varieties should be put as far away from all windbreaks as possible. The rows should be planted in the direction of prevailing winds and far enough apart to permit air to circulate freely among the branches so that the excessive moisture on the plants from dew and rain will dry up quickly. Do not let any plants, even wild ones, mature during the cutting season. Late in the fall when growth is over cut out and burn the old plants. Destroy any wild asparagus plants that may be growing in the neighbourhood of the asparagus bed. Spraying with Bordeaux mixture and dusting with sulphur have been tried and fair results obtained in the United States. Spraying or dusting, however, is a difficult

and costly undertaking and it is doubtful whether it would pay here in Ontario.

BEANS

Anthracnose or Pod Spot—This is the most common and most serious disease to which beans are subject. In wet seasons it causes great loss by destroying both garden and field beans.

Symptoms—Pods, seeds, leaves and stems are affected. On the pods sunken, reddish-brown or black spots, usually with rusty brown borders, are seen. In the centre of these spots a pinkish coloring may be noticed frequently. Affected seeds show dark brown or rusty discoloured spots. These are often very minute. On the leaves the chief symptom is the brown and rusted appearance of the main veins underneath. Sometimes these appear as if cut or eaten out by the fungus. Occasionally small holes appear in the leaf. These are due to the destruction of the smaller veins by the fungus. On the stems, rusty brown, elongated spots are sometimes seen. Occasionally these spots are so deep as to cause the stem of the leaf to break at this point.

Cause—This disease is caused by the fungus *Colletotrichum lindemuthianum* (Sacc. & Magn.) Bri. & Cav. This fungus passes the winter chiefly as dormant fungus threads (mycelium) in infected seed and possibly to some extent as spores on the seed. It is also known to winter over on diseased plant refuse left in the field and in beanstraw. This fungus, however, does not live long in the soil when separated from its host. The seed can be infected only through the pod, that is, the fungus threads (mycelium) penetrate through the tissues of the pod into the seed beneath so that pods that are spotted with anthracnose contain infected seed while those that are free from spots contain non-infected seed. When infected seed is sown in the spring the fungus threads inside become active and grow, and the first crop of spores of the season is produced on the seed leaves (cotyledons) of the seedlings. From these they spread to the true leaves and stems and later to the developing pods. The spores of this fungus are held together on the surface of the affected parts by the gelatinous nature of the spore-coat, and are only scattered when the beans are wet with rain or dew which dissolves the gelatinous substance by which the spores are glued to the surface of the pod.

Bean Anthracnose Pods, showing the spots characteristic of the disease.
(Courtesy of the Department of Plant Pathology, Cornell University.)

Control—Use non-infected seed. Such seed can be secured by selecting it from disease free pods. This method is simple and satisfactory for small garden plots of beans and for a seed plot from which to secure the seed supply of field beans for the following year. In the fall of the year after the beans ripen, gather enough disease free pods to supply the seed necessary for the following season. Clean seed alone, however, is not enough to insure a healthy crop. It must be planted far enough away from other bean fields so that the spores will not be carried from the diseased plants to the healthy plants grown from clean seed. If Anthracnose is bad beans should not be planted on the same ground oftener than once in three or four years. Beanstraw should never be used for manure with the bean crop. It is not advisable to work among beans when they are wet with rain or dew as the spores of the fungus which causes the disease are easily scattered at this time. Some varieties of beans are much more resistant to Pod Spot than others. These varieties of beans can be used to advantage. Robust Pea Bean, Wells Red Kidney, Perry Marrow, The York, The Geneva and the New Nova Scotia Marrow are varieties of dry beans which show a marked resistance to Pod Spot. There are a number of varieties of wax and green pod, bush and pole beans which are more or less resistant. Burpee's stringless green pod has shown marked resistance in field trials here at Guelph.

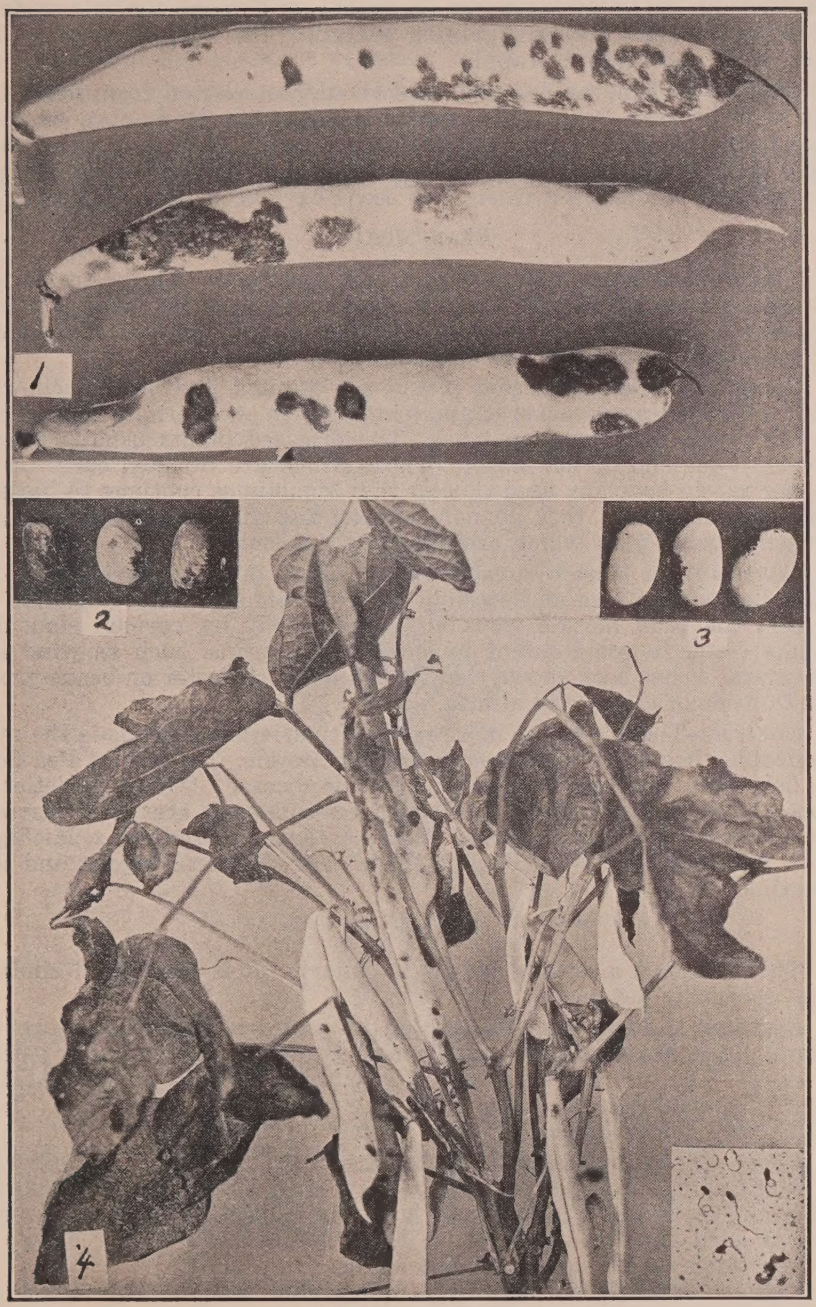
Bean Blight or Bacteriosis of Beans

This is the most serious bacterial disease of the bean in Ontario.

Symptoms—This disease is characterized by a marked spotting of the leaves, stems, pods and seeds within the pods. Wilting occurs when the veins of the plant are invaded. On the leaves, spots appear around the point of infection as "water-soaked" dark green or translucent areas which enlarge and form irregular blotches, yellowish to brownish in colour. These areas may coalesce and rupture so that the leaves take on a ragged appearance. When the plants are succulent a light amber coloured sticky fluid oozes from the diseased parts and later dries to form a thin shiny scale on the surface. On the stems and leaf petioles, "water-soaked" areas appear at points of infection; these may extend lengthwise or they may girdle the stem. Later they become dry and brittle, and this results in breaking of the stems and defoliation of the plant. On the pods, water-soaked spots develop into enlarged reddish-brown blister-like cankers, which are often slightly raised above the normal surrounding tissue. Frequently the seeds within the pods become infected from the diseased spots on the pod. If such occurs when the seeds are young they fail to mature and become shrunken and discoloured. If the seeds are nearly mature before they are affected they become covered with the sticky varnish-like coating, consisting of a large number of the disease producing bacteria; these bacteria may remain alive for several years in this state. For this reason seed from diseased plants should not be sown. Sometimes the cotyledons or seed leaves become infected, and in such instances the veins (vascular system) of the young plant become plugged with the bacteria; this results in wilting and death of the plant.

This disease can be differentiated from Anthracnose or Pod Spot of beans by comparing the symptoms described above with those of Anthracnose.

Cause—This disease is caused by *Phytomonas phaseoli* (E. F. Smith) Bergey et al. These bacteria gain entrance to the various parts of the



BACTERIOSIS OF BEANS

1. Diseased pods.
2. Diseased beans from diseased pods.
3. Healthy beans.
4. Bean plant badly affected with bacteriosis in foliage and pods.
5. Ps. phaseoli, the cause of the disease.

plant through the breathing pores (stomata), or through wounds made by insects, cultivators, etc. On gaining entrance, the bacteria feed on the plant juices and multiply rapidly.

Control—Whenever possible, seed should be selected from fields free from this disease. Bean straw should not be used as manure on fields where beans are to be grown, and as long a rotation of crops as practicable should be followed. It should be remembered that infected seeds will produce infected plants, even when such seeds have been kept for years.

Bean Mosaic

This disease is common in Ontario. It sometimes causes very serious loss especially to pea beans. Certain strains of pea beans have had to be discarded on account of their susceptibility to this trouble. Wax beans and green pod bush beans are also subject to Mosaic.

Symptoms—Badly affected plants are stunted and sickly yellow in colour with the leaves puckered and mottled with an alternate light greenish-yellow and dark green patches. The diseased plants usually remain alive until the end of the season. Those which are infected early in the summer rarely bear any seed though they sometimes continue to blossom until autumn. Those that do not contract the disease until late in the summer develop pods which are apparently normal.

Cause—Bean Mosaic is caused by a virus which is carried over the winter in the bean seed and possibly also in white sweet clover plants. In the field the bean mosaic virus is spread chiefly by various plant lice (aphids), and to some extent by mechanical means, such as wind and cultivators. It has been shown that it spreads much faster on beans grown close to fields of clover and alfalfa.

Control—The use of the more resistant varieties of beans is the most practical method of avoiding loss from Bean Mosaic. The Robust Pea Bean is a field bean immune or nearly so to this disease. *Other varieties of beans which are resistant in various degrees to Mosaic are: Red Marrow, White Marrow, Long Pod, Keeney Rustless, German Black Wax, Michigan White Wax, Refugee Wax, Prolific Black Wax, Scarlet Flagolet and Red Valentine.

Bean Rust

This is seldom a serious disease in Ontario. It is seen on all kinds of beans, especially pea beans.

Symptoms—Rust spots appear on all parts of the plant above the ground. They are, however, usually most numerous on the under side of the leaves. The rust spots are distinctly circular, slightly raised. At first they are reddish-brown in colour, later in the season they turn black. They may be very numerous on the under surface of the leaves.

Cause—The fungus which causes bean rust is *Uromyces appendiculatus* (Pers.) Lev. This fungus produces red rust spores (urediniospores) and black rust spores (teliospores) on the lower surface of the leaves and other affected parts of the plant. It is carried over the winter chiefly as the teliospores on the old leaves and stems.

Control—The easiest way of avoiding this disease is by using the more resistant varieties. Pole Beans are more susceptible to rust than are bush varieties. Green Pod strains are less resistant than wax pod ones. Nothing has been done in Ontario in the selection of resistant varieties

*Manual of Vegetable Garden Diseases by Charles Chupp.

as bean rust has never been a serious disease in this Province. Experimental work carried on in Virginia has supplied us with the following lists of more or less resistant varieties:

Resistant varieties of pole beans: Marblehead, Tennessee Wonder, Brockton, Indian Chief, Everbearing.

Resistant varieties of bush beans: Hodson Green Pod, Early Refugee, Mexican Red, Golden Eye, Detroit, Hodson Wax, Wells Red Kidney, White Kidney, Yellow Eye.

Leaf of beet attacked by leaf-spot fungus
(*Cercospora beticola* Sacc.)

BEETS

Leaf Spot—This disease is very common in Ontario but seldom causes serious injury to garden varieties. In some seasons it severely injures the leaves of sugar beets and mangels.

Symptoms—It is easily recognized by the small white or brown spots with purple margins which are scattered irregularly over the leaves. In the later stages of the disease these spots become ash-grey in colour. When they are very numerous the leaves wither and die. Sugar beets severely injured by this disease develop long crowns and are not desirable for sugar purposes.

Cause—This disease is caused by the fungus *Cercospora beticola* Sacc. The spores of this fungus are scattered by rain, insects, cultivating tools, workmen and wind. It passes the winter in the old infested refuse or on the seed. High humidity and temperature increase infection by this fungus.

Control—Plow under the old leaves deeply in the fall. Do not grow beets or closely related plants (mangels and Swiss chard) on the same

ground oftener than once in two or three years. In small gardens rake up the diseased leaves and burn them or feed them to cattle. If the leaves of sugar beets or mangels are harvested and placed in the silo the fermentation will destroy the fungus. Spraying with Bordeaux every two weeks or ten days will control this disease but is seldom necessary.

CABBAGES

Club Root—This is a disease of cabbage, cauliflower, turnips, radishes and other members of the mustard family (Cruciferae). It is a very troublesome disease in the Maritime Provinces, and is occasionally found in Ontario, especially in market gardens in the vicinities of our larger cities.

Symptoms—Affected plants are noticed to flag or wilt markedly and if their roots are examined irregular thickenings and knob-like swellings are found upon them. These often reach the size of a man's fist. The tops of diseased plants develop very slowly. Affected cabbage and cauliflower plants form little or no head. Sometimes the plants are completely killed. Late in the season the diseased roots may rot.

Cause—This disease is caused by a slime fungus known as *Plasmodiophora brassicae* Wor. This is a soil organism that may remain in the soil for several years. It is spread in seedling plants, in contaminated manure, on farm implements and on the feet of man and animals. It may be washed from high to low land by running water. Experiments have shown that this parasite does not thrive in soil which is highly alkaline and that it does most damage in poorly drained acid soil. It is stated that the spores germinate and infection takes place readily only when the soil is warm and wet.

Control—The choice of well drained soil, the destruction of weeds belonging to the mustard family, the practice of long rotation of crops and the necessary precautions to prevent the planting of infected cabbage and cauliflower seedlings are very important measures in the prevention of this disease. The location of the seed bed is important. (It should be so situated that it is not subject to being washed by water running down from higher ground above it.) The position of the seed bed should be changed from time to time or the soil in it renewed or sterilized with steam. Seedlings should be carefully inspected for any evidence of Club Root. If any infected seedlings are discovered all of them should be discarded as many of them will probably develop the disease if they are planted out. If seedlings must be grown in infested soil, corrosive sublimate should be used to disinfect the soil about the roots of the seedling plants. It has been found to reduce Club Root infection even when the slime fungus is present in the soil. One ounce to ten gallons of water is recommended for the prevention of Club Root in cabbage seedlings. The first application should be made as soon as the plants are through the soil. Four or five additional applications should be given at weekly intervals. Cauliflower seedlings are more subject to injury from corrosive sublimate than are cabbage seedlings. It is, therefore, advisable to use a greater dilution, one ounce corrosive sublimate in fifteen gallons of water for the first application and one ounce in twelve gallons for the others. In preparing the corrosive sublimate solution, dissolve the required amount of the powder in a little hot water and then dilute to the required strength with cold water. Prepare the solution in an earthen or wooden vessel as the

corrosive sublimate corrodes metal. A watering can with the sprinkler removed can be used to apply the corrosive sublimate along the rows so as to moisten the soil around the roots of the plants. If a few diseased plants are found in the field they should be burnt at once. If the soil becomes infested a long rotation of crops should be practiced. Plants belonging to the mustard family should not be grown in such soil oftener than once in six or eight years. If it is impossible to follow a long rotation of crops, and cabbage, cauliflower or turnips must be planted in infested soil, an application of hydrated lime or quick lime should be given six or eight weeks before the plants are set in the field. The field should be ploughed and enough hydrated lime (or quick lime, if preferred) scattered over the soil and harrowed in to produce an alkalinity slightly above neutral (pH 7.2). On some soils only a few hundred pounds per acre are necessary while on others as much as three tons per acre are required. Soil samples

Club Root of Cabbage (Original)

may be sent to the Chemistry Department, Ontario Agricultural College, to have determined the amount of lime per acre necessary to apply to any given field to make the soil alkalinity slightly above neutral. The kind of lime is very important. Experiments have proved that only hydrated lime or quick lime can be used profitably in the control of Club Root. Varieties of turnips resistant to Club Root are now available to growers who have trouble with this disease.

Blackleg of Cabbage—This disease is not confined to cabbages but is seen also on cauliflowers, Brussels sprouts, Swede turnips, kohl-rabi, kale, rape, radish and several other cultivated plants belonging to the mustard family. In this Province cabbage and cauliflower are the only crops which are severely affected by this disease.

Symptoms—Plants may show the disease in the seed bed or in the field. Near the base of the stem are seen oval, depressed, light brown cankers. These enlarge and girdle the stem. The affected tissues turn black and the stem and roots decay. The blackening of the base of the stem has led to this disease being called Blackleg. Light brown spots may also appear on the leaves. In the cankers on the stem and in the spots on the leaves, numerous black dots (the fruiting bodies of the fungus) may be seen. Badly diseased plants may wilt. Sometimes the edges of the leaves turn bluish red in colour. If the stems and roots of the older plants decay the weight of the heads causes them to lean or fall over. Affected plants usually die in a comparatively short time but in damp soil they may live for a long time and even form heads.

Cause—Phoma lingam (Tode) Desm. is the fungus responsible for this disease. It passes the winter as fungus threads (mycelium) in the seed and as spores and fungus threads on the seed, and with the cabbage refuse in the soil. This fungus remains alive in the soil as long as any particles of cabbage or cauliflower stalks are left intact. It is disseminated in soil or manure containing cabbage refuse. Spring freshets carry the spores over large areas of a field or from one field to another. It is also spread on cultivating tools and by insects. The fungus appears to require abundance of moisture before it will develop rapidly, as the severity of the disease appears to be in direct proportion to the amount of rainfall in the early summer.

Control—Arrange a rotation of crops in which cabbage, cauliflower and other plants belonging to the mustard family are not grown on the same soil oftener than once in every four years. Rake up and burn the refuse from the diseased crop. Do not use seedlings from a seed bed in which there is any indication of Blackleg. Use non-infected seed. Such seed can now be secured from the Puget Sound section of the United States where the disease does not normally occur. If the source of the seed is unknown it is advisable to treat it with corrosive sublimate or hot water. The directions for treating the seed with corrosive sublimate are as follows: Use a solution of corrosive sublimate of the strength of 1-1000 by weight, which is prepared by dissolving one tablet in a pint of water, or an ounce of corrosive sublimate powder in 6 gallons of water. Place the seed in a cheesecloth bag. Do not fill the bag more than half full. Then immerse it in the solution for twenty to thirty minutes. After this rinse the seed thoroughly in clean water, then spread it out to dry. Corrosive sublimate is a comparatively handy seed disinfectant but it does not give as complete control as does hot water. This is due to the fact that while it will kill all the fungus which adheres to the outside of the cabbage seed, it cannot kill the fungus threads (mycelium) within the seed. Corrosive sublimate corrodes metal and therefore earthen or wooden vessels should be used to mix it in. Seed may be disinfected by immersing the bags in water heated to a temperature of 122° F. for 30 minutes. When the bags are immersed in the water it should be kept stirred constantly and the temperature maintained at 122° F. by adding, from time to time, small amounts of boiling water. After the bags are removed from the hot water they should be dipped in cool water, after which the seed should be spread out to dry. This treatment is very effective but it reduces the germination of the seed to a very considerable extent.

Bacterial Wilt of Cruciferae (Black Rot of Cabbage)

1 and 2. Views in a cabbage plantation, showing numerous cases of the disease in all stages of development.

Bacterial Wilt or "Black Rot" of Cabbage and Cauliflower

This is a bacterial disease of the veins (a vascular disease) of cruciferous plants—cabbage, cauliflower, kohl-rabi, Brussels sprouts, broccoli, turnips, rape, kale and radishes.

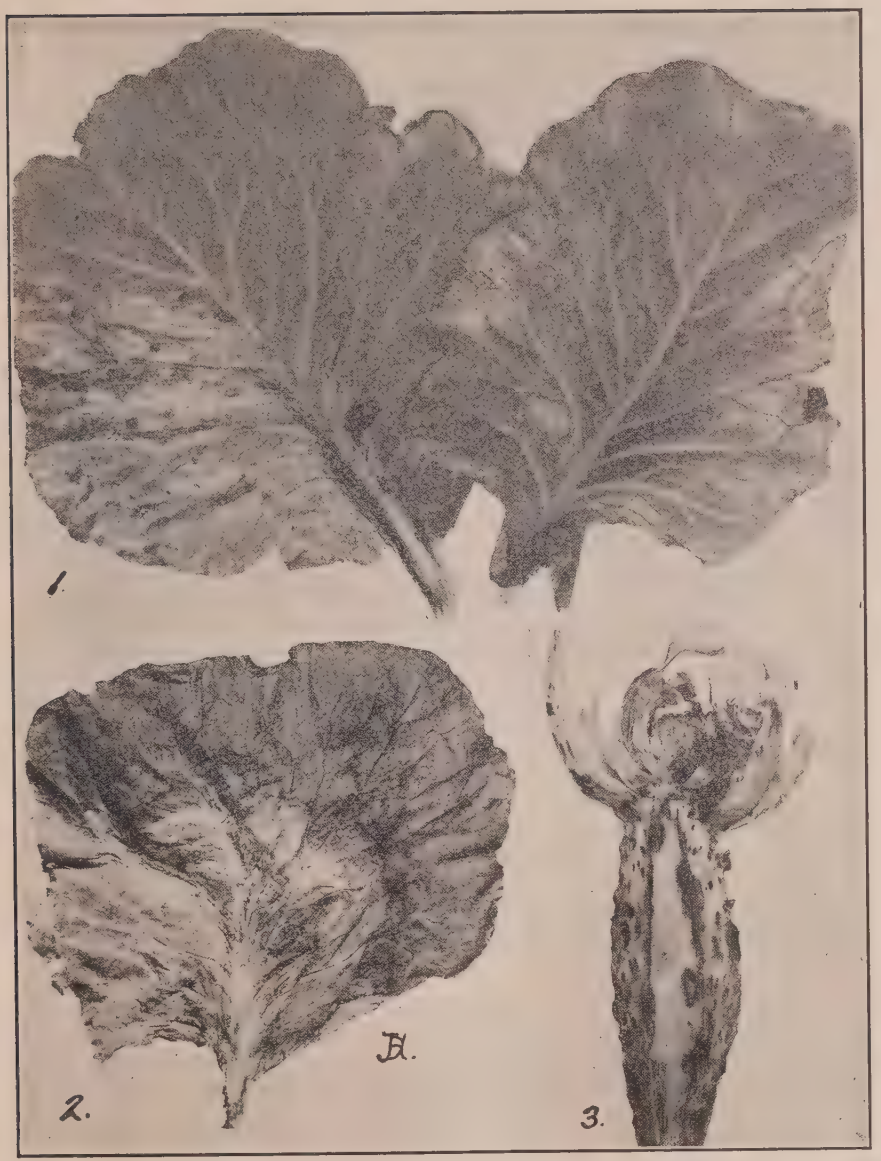
In vascular diseases the bacteria invade the veins or water-conducting vessels of the plant and cause wilting by plugging the veins.

Symptoms—When infection occurs in the seedling stage or in very young plants, death of the plant usually results. Those that do survive remain stunted and fail to produce a root in the case of the turnip and radish, or fail to form a head in the case of cabbage and cauliflower. Primary infection is through the veins of the leaf which turn brown as the bacteria advance down them towards the stem, eventually reaching the middle of the plant and spreading to adjacent parts. This is followed by secondary invasion of the plant by other kinds of bacteria which soon cause a rot with an objectionable characteristic smell. Infected leaves are characterized by yellow to brown irregular shaped blotches, somewhat transparent, and usually starting near the outer margin of the leaf, later progressing towards the middle until the entire leaf is involved. The network of veins become blackened to such an extent that they may be seen as black threads, even in the thick white tissues surrounding them in the midrib. If the stems of infected leaves are cut across, the veins will appear as small black dots instead of white or greenish-yellow dots as they appear in healthy sections; in longitudinal sections of diseased stems the veins appear as black streaks. When diseased leaves are broken from the stem, the veins connecting the stem and leaf appear as black dots. Wilting of the leaves may occur after the bacteria have entered the central stem of the plant. This condition is brought about by the large number of organisms plugging the veins and interfering with the circulation of the sap.

Cause Phytomonas campestris (Pammel), Bergey et al, is the cause of this disease. The organism is carried over from year to year chiefly in the soil and in manure containing diseased crop refuse. Once a diseased crop has been produced in a field the soil remains infested for several years. Infected seed is known to carry the organism to disease-free soil.

Most of the infections occur through the water pores of the leaf, which are situated in groups around the margin. During cool nights these water pores exude dew-like drops and these may persist for some time during moist weather. When the disease producing organisms reach these droplets they multiply rapidly and gain entrance to the veins, causing infection. Sometimes the organism gains entrance to the plant through wounds. Aphids, slugs and other insects have been shown to transmit the bacteria from diseased to healthy plants. By these methods of transferring the organism many individual infections may occur on a single leaf, but it requires from 7 to 20 days after the entry of the organism before the symptoms appear.

Control—It will be obvious from the above description that the old and still common practice of removing diseased leaves from an infected plant does not control the spread of the disease. Infected plants and seedlings should be pulled and burned. If such material is thrown on the manure pile the infection will, in all probability, be transferred with the manure. Infected cabbage heads should never be stored after harvesting since the disease may spread during storage. Rotation of crops is recommended, and cruciferous plants should be eliminated from the rotation for 4 or 5 years.



Bacterial Wilt of Cruciferae (Black Rot of Cabbage).

1. Cabbage leaves affected with the bacterial wilt or black rot. The lighter-shaded areas around the outer edge of the leaves are the diseased parts showing natural inoculation through the water pores on the edge of the leaves; the light-shaded areas were yellow.
2. The lighter-shaded part of the leaf near the base indicates the disease, and the blackened vascular bundles of the stem, where it is cut, indicate that the disease entered this leaf from the main stalk of the cabbage.
3. Cabbage stalk and stunted head; the blackened vascular bundles indicate that the disease was general throughout the plant. The leaf of Fig. 2 was taken from this plant.

The position of the seed bed should be changed from time to time, or the soil in it renewed or sterilized with steam or formalin.

Seed disinfection is recommended. This can be accomplished either by immersing the seed for 30 minutes in a solution of corrosive sublimate (mercuric chloride), 1 part by weight in 1000 parts of water (1 tablet to a pint of water), or in a formalin solution, 1 pint to 30 gallons for the same time.

In disinfecting the seed use cloth bags and only half fill them so that the solution will penetrate to all the seeds when they are immersed. After treatment rinse in clear water and spread out to dry.

CELERY

Late Blight or Septoria Leaf Spot

This is the most common and most destructive celery disease in Ontario. In wet seasons it is very severe and ruins large quantities of celery. It is not usually noticed by the grower until the disease has become fairly well established on the plants, but a careful observer can often find a little of it in the seed bed or in the field shortly after the plants are set out.

Symptoms—The lower leaves usually show the first symptoms of the disease. On these brown spots develop and in these spots numerous black specks may be seen. These black specks are the fruiting bodies of the fungus. They are called pycnidia and contain the spores. There are two forms of Late Blight, the large spot form and small spot form. In the large spot form, the spots, when mature, are definite in outline, brown to reddish-brown in colour with a darker margin and with pycnidia scattered in the centre. These spots may increase in size until they have a diameter of one-quarter inch or more. In the small spot form, the spots are indefinite in outline, brownish-black or even grey in colour. The pycnidia are found within the spot or in the tissue surrounding it. The diameter of these spots is seldom more than one-eighth inch. When this form of the disease is very bad, the characteristic spots may not develop but the whole leaf may become covered with minute black specks (pycnidia). Such leaves become dry and wither up.

The small spot form also affects the stems causing somewhat water-soaked rusty-brown areas studded with black pycnidia. This phase of the disease is often erroneously called Celery Rust by the growers. If diseased stems are put in storage secondary fungi, or bacteria, develop causing decay.

Cause—The large spot is caused by the fungus *Septoria apii* (Br. & Cav.) Chester. The small spot is caused by the fungus *Septoria apii-graveolentis,* Dorogin. Numerous spores are produced in the black specks (pycnidia) embedded in the surface of the leaves. When the plants are wet with rain or heavy dew the spores are discharged and spread by means of water, wind, insects, implements, men and horses. The fungus lives over winter on the diseased leaves and stems left lying on the field or in the seed beds.

Control—Spraying with Bordeaux or dusting with copper-lime dust is the most reliable means of controlling this disease. Spraying has given the best results in experiments carried on at the college, but some growers

Late Blight of Celery (Small Spot Form).
(Courtesy of the Department of Plant Pathology, Cornell University).

have had satisfactory results with dust applied frequently with high pressure.

In addition to spraying or dusting the following precautions should be taken, and those who are growing only a small quantity of celery may be able to do so without spraying or dusting. Rake up and burn any diseased leaves and stems and follow a system of crop rotation. This allows the refuse from the celery crop to decay before celery is grown again on the same soil. Plant the celery in well drained land. Do not cultivate when plants are wet and keep the soil from getting into the crown of the young plants.

Spraying—Give two applications when the plants are still in the seed bed using Bordeaux mixture of the strength of 3 pounds of bluestone and 4 pounds of hydrated lime to 40 gallons of water. The first application should be made when the plants are from two to three inches high and the second application given a short time, three or four days, before setting the plants out in the field. The field spraying should be started a week or

ten days after the plants are set out. For the field applications use Bordeaux mixture of the strength of 4 pounds of copper sulphate, 5 pounds of hydrated lime and 40 gallons of water. Applications should be made at an interval of a week or ten days during the season. The wetter the weather the greater the number of applications that will be required. When the plants are small 40 gallons of the spray mixture will be sufficient for an acre but when the plants are large it will require two or three times this much. It is very important that the Bordeaux should be applied under high pressure. The sprayer should be rigged with three nozzles to each row, one from the top and one from each side. Late Blight spreads most rapidly during wet weather. It is therefore important to see that the Bordeaux is on the plants before rain comes rather than after.

Dusting—Use 20 per cent. copper-lime dust. Give two applications as described above while the plants are still in the seed bed and repeat at intervals of from 3 to 10 days after the plants are set out in the field. In very wet weather, if blight gets started, it may be necessary to apply the dust as often as twice a week. The best results from dusting are secured by using liberal quantities of dust and applying it under high pressure when the plants are damp with dew.

Early Blight or Cercospora Leaf Blight

This disease compared with Late Blight of celery is of comparatively little importance in Ontario. It is seen to some extent every year and occasionally it does considerable damage.

Symptoms—The name "Early Blight" is misleading as this disease does not usually appear until later in the season than the so-called "Late Blight." Usually it does not appear until the plants are from 6 to 8 weeks old while Late Blight is often seen shortly after the seedlings come above the ground. On affected leaves small yellow spots develop. These enlarge and become somewhat circular to angular in shape with a brown margin. The central part of the spots change from yellow to ash-grey in colour. When numerous they run into each other in irregular patches.

Cause—Cercospora apii Fres. is the fungus which causes this disease. This fungus produces numerous spores on the surface of the leaves when the weather is hot and wet after a period of drouth. These spores are spread from plant to plant by rain and wind and during cultivation. The fungus is carried over the winter as hardened masses of mycelium (sclerotia) in the tissues of the diseased leaves.

Control—The recommendations given for the control of Late Blight of celery apply in all their details to Early Blight.

Celery Yellows

This disease was reported as occurring in Ontario for the first time in 1924. In the United States celery yellows has caused serious loss to celery growers especially in the State of Michigan. It is recorded as being most serious on certain strains of golden self blanching celery. These are said to be more susceptible than white plume and other winter varieties.

Symptoms—Affected plants are stunted with yellow or yellowish-white leaves. They usually die prematurely. The veins (vascular bundles) of the roots and heart are reddish-brown in colour.

Cause—This disease is caused by a species of Fusarium. This fungus is a soil organism, being carried over in the soil from year to year. Land badly infested with it is said to be worthless for the growing of many of

the finer strains of golden self blanching celery. On account of the serious losses which may be caused by this disease Ontario celery growers should be on the watch for it.

Control—In Michigan it has been found that this disease can be avoided by growing resistant strains of golden self blanching celery. Such strains have been developed in Michigan and if Ontario celery growing soils become infected with the fungus which causes yellows, it may be necessary to introduce these resistant strains into this Province, or to develop here in the Province other resistant strains.

Bacterial Spot Disease of Celery

This disease occurs on all varieties of celery grown in Ontario. When severe it disfigures the leaves to such an extent that the celery is not readily saleable.

Symptoms—This leaf spot is characterized by irregular circular rusty brown spots, rarely exceeding a quarter of an inch in diameter. These spots closely resemble those of late blight but may be distinguished from them by the absence of the little black specks (fruiting bodies) of the fungus which causes late blight. The disease is usually confined to the leaf blades, causing disfiguration and sometimes death of the leaf.

Cause—This disease is caused by the bacterial species *Phytomonas apii* (Jagger), Bergey et al, which enters the leaf through the breathing pores (stomata) or through wounds made by insects.

Control—Spraying experiments have shown that liquid Bordeaux mixture will satisfactorily control this disease. See directions for spraying celery under Late Blight of Celery, page 16.

CORN

Corn Smut

This smut is very frequently seen in Ontario and nearly everyone who grows any corn is familiar with it. Sweet or table corn seems to be especially susceptible to it.

Symptoms—Corn smut attacks the ears, stalks, leaves and tassels. On the parts affected it produces peculiar growths frequently spoken of as "boils." These "boils" are sometimes six inches or more in diameter. In the early stages they are green, later they are white and polished, and finally they become dark coloured and ruptured, exposing a brownish black mass of powder consisting of millions of spores. Corn smut usually appears on the plants when they are about three feet high, but on very susceptible varieties like Golden Bantam it is sometimes seen when the plants are less than a foot high.

Cause—The fungus which causes corn smut is *Ustilago zeae,* (Beckman) Unger. As soon as the "boils" mature and rupture, the spores are scattered by the wind and other agencies. In the soil or in manure they germinate and produce great numbers of secondary spores which may infect any of the tender growing tissues of the corn plants. Thus the smut is spread during the growing season. The fungus is carried over the winter as spores in the soil and in manure. These may be contaminated in various ways. The spores may be scattered by the wind or the spore mass may be left in the field, or thrown on the refuse or on the manure pile. It is believed that the spores of this fungus may not only live in the manure pile but that they may actually grow and increase in number in warm fermenting manure.

Control—No seed treatment will prevent corn smut as the fungus which causes it is carried over the winter as spores in the soil and in manure. Control measures are not very satisfactory. The cutting out and burning of all smut growth "boils" as soon as they appear is recommended for gardens or small areas of sweet corn. This should be done before they mature and break open, and care should be taken in handling them that they are not broken open and the spores they contain scattered in the field. This practice should be followed every year. If possible practice a rotation of crops. The spores of this fungus will not live for many years in the soil and those which are in the soil cannot injure any other garden crop. After three or four years corn may be planted again with less danger as many of the spores will have lost their vitality by this time. Avoid fresh manure with the corn crop as it is very likely to contain live smut spores.

Corn Smut on Ear and Tassel. (About one-half natural size).

Stewarts Disease or Bacterial Wilt of Sweet Corn

This disease was not noticed to any extent in Ontario until 1932. That year sudden outbreaks occurred in the counties of Essex, Kent and Norfolk where the degree of infection varied from 3 to 70 per cent. The disease also occurred in Elgin county but with less severity. The casual organism was found in 13 per cent. of imported and home grown seed, examined at that time. It is deemed advisable to include an account of this disease here, so that, in the event of its recurrence, it may be recognized.

Symptoms—This is a disease of the veins (vascular disease) which results in wilting, even when there is no lack of moisture in the soil. The first signs of the disease to appear are long, wilted streaks, lighter green

in colour than adjacent still healthy parts of the leaf blade, but without conspicuous yellowing. These streaks are usually noticed first at the lower part of the plant, where infection comes from the seed, soil, and other sources. The disease spreads from such points until the whole plant wilts and dies, but even after death of the plant the green colour of the leaves usually persists. In some instances the tassels may develop prematurely then die before the plant as a whole succumbs. When the stem of an affected plant is cut across, yellowish beads of sticky bacterial slime will ooze from the veins. This slime does not ooze to the uncut surface of the plant except through breathing pores in the skin of inner husks of badly diseased plants. While this is primarily a disease of the veins, the bacteria may, in advanced stages of the disease, invade all parts of the plant. Both sweet and field corn may be affected but sweet corn is the more susceptible.

Cause—This disease is caused by the bacterial organism *Phytomonas stewarti* (E. F. Smith) Bergey et al, which enters the plant from the seed, or through wounds made by the 12-spotted cucumber beetle which carries the organism from infected plants; or through leaf wounds made by the brassy flea beetle, and the toothed flea beetle. The organism overwinters in infected seed.

Corn leaves affected with Bacterial Wilt.
(Courtesy of Dr. Berkley).

Corn affected with Bacterial Wilt.
(Courtesy of Dr. Berkley).

Control—Seed treatment has not proved to be satisfactory in controlling this disease. It would appear that the best way of avoiding this trouble is to be careful in the source of seed. Whenever possible, seed should be secured from fields free from the disease. If this disease should again be troublesome in Ontario it will be necessary to endeavour to grow resistant strains of corn. From work done at the Connecticut Agricultural

Experimental Station* it would appear wise to select seed from disease-free plants in areas where the disease is present. The progeny of these plants is more likely to be resistant.

*Circular 96. Connecticut Agr. Sta., New Haven, U.S.A.

CUCUMBERS

Bacterial Wilt of Cucumbers

This is a widely spread and destructive disease of cucurbits. The cucumber is the most susceptible, but muskmelons, pumpkins and squash may also be affected by it.

Symptoms—The most striking symptom of this disease is a wilting of the plant first noticed at the extreme tips of the runners. The affected leaves and other parts become limp and lose their bright green colour and take on a dirty, yellowish-green appearance. Since this is a disease of the veins the whole plant eventually wilts. If the diseased stem is cut through, a clear, sticky, slimy liquid will ooze out from the veins at the cut surfaces. This sticky, slimy sap is one of the most characteristic symptoms of the disease.

Cause—This wilt disease of cucumbers is caused by the bacterial organism, *Erwinia tracheiphila* (E. F. Smith) Holland. The organism is transferred from diseased to healthy plants by the striped and 12-spotted cucumber beetles. It is carried over from season to season in the bodies of the overwintering striped cucumber beetles. It has been shown repeatedly that the organism is not carried over in the soil. It has also been shown that it is not transmitted through the seed, and all attempts to produce the disease by artificial inoculation have failed.

Control—The most important point in the prevention of this disease is the control of cucumber beetles which harbour and spread the causal organism. Professor Caesar recommends dusting the plants from above with gypsum (land plaster) and arsenate of lime (calcium arsenate) in the proportion of 20 parts of the former to 1 part of the latter. If wilt is to be prevented apply this dust as soon as the beetles are observed, and repeat as often as may be necessary to protect the plants from the beetle. Usually 3 or 4 applications are all that are required. It is also advisable to remove and burn or bury all infected plants to prevent insects feeding on them and spreading the disease. *"It has been found that the American varieties, such as Chicago pickling, and other related pickling strains are much less susceptible than are similar varieties originating in Europe, such as Half Long Prolific, Oblong Green Pickling, King William, Short Green Parisian, and others. Where wilt has been severe, the American varieties should be chosen though they are far from immune."

Angular Leaf Spot of Cucumbers

This disease has not caused such serious losses to cucumber growers in Ontario as the wilt disease, but it often causes considerable damage and warrants careful control.

Symptoms—When young seedlings are infected the seed leaves show small water-soaked spots. Later, these become brown and die. If the seedlings survive, the second or true leaves become infected, and develop the characteristic spots. These spots are at first darker green than the

*Bulletin 206. New York State College of Agr., at Cornell University, Ithaca, N.Y.

surrounding tissue, and are water-soaked in appearance, later they turn dry and brown, and drop out, giving a ragged appearance to the leaf. Because of this last symptom the disease is often referred to as the "shot-hole" disease. The spots are always irregular or angular in shape because

Bacterial Wilt of Cucurbits.

1. Bacterial wilt of cucumber.
2. Bacterial wilt of cucumber.
3. Bacterial wilt of squash.
4. Stained microscope preparation from the viscous slimy exudate of a vascular bundle of a wilting cucumber plant, showing the bacteria *(Erw. tracheiphila)*, (X 1000 di).

they occur between the veins. If one examines these spots before they become dry, there will be noticed a milky white ooze or exudate which is a teeming mass of the bacteria. When the fruit-producing flowers are affected they darken in colour, dry up and fail to set fruit. When the fruit is affected, small circular water-soaked spots appear, mostly on the upper surface, and on these appears a resinous exudate. From this stage very little development of the spots takes place on the surface of the fruit, but the rot progresses into the fruit, eventually reaching the veins and the walls of the seed chambers (placentae), changing the interior of the fruit to a soft mushy mass.

Cause—The bacterium *Phytomonas lachrymans* (Smith & Bryan) Bergey et al, causes this disease. It overwinters on infected seed and in the soil. It is spread from diseased to healthy plants by insects, wind and pickers. The organism gains entrance to the plant through the breathing pores (stomata) of the leaves and fruit.

Control—Seed treatment is the most effective method of control. Simply tie the seeds loosely in a cheesecloth bag and soak them for 10 minutes in corrosive sublimate, 1 part to 1000 parts of water (1 tablet to a pint), rinse in several changes of fresh water and dry them. Remember that corrosive sublimate is a deadly poison. When the disease is found on the foliage, its spread may be checked by spraying with Bordeaux mixture. Crop rotation is recommended in cases where the disease is established. Cucumbers should be omitted from the rotation for at least two years, if this is possible. It is important also to avoid working among the vines when they are wet with rain or dew.

Mosaic of Cucumbers

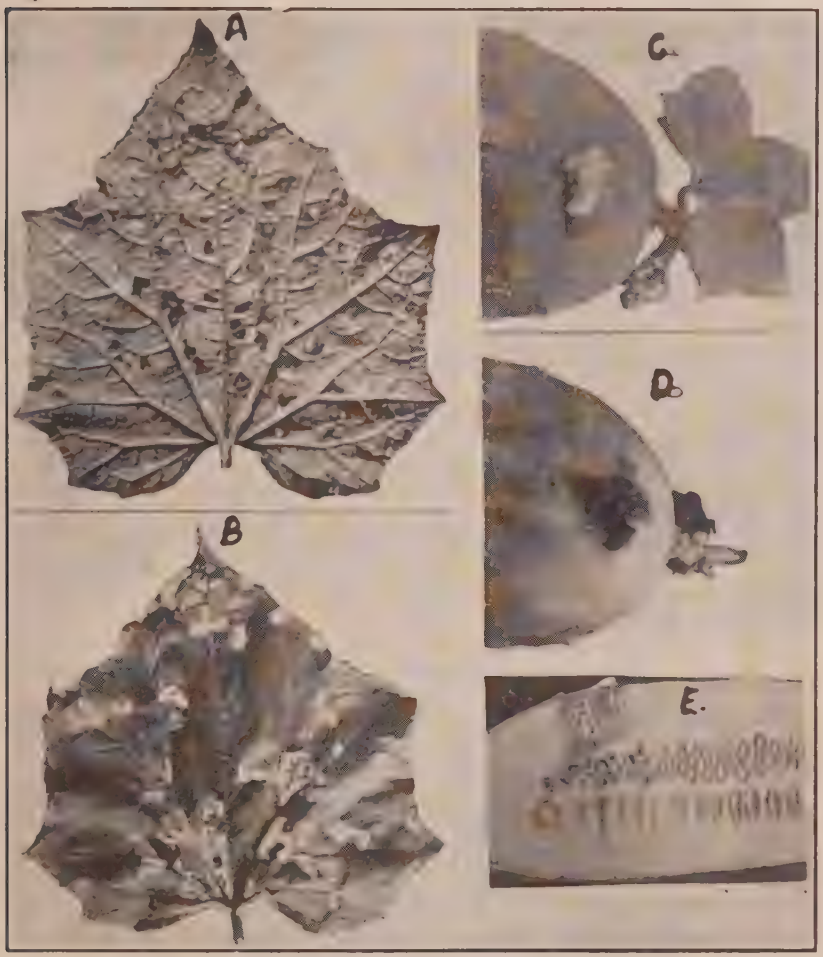
This disease is often seen in Ontario. It frequently causes very serious loss to cucumber growers. It is known by various names such as Mosaic, White Pickle, White Wart and Nubbin disease.

Symptoms—Plants may show symptoms of the disease in any stages of their growth. If seedlings are diseased the seed leaves (cotyledons) turn yellow. The leaves are mottled yellow and green and the plant is much dwarfed. There is little or no fruit set and the plant usually dies early. Generally plants do not show symptoms of the disease until they have passed the seedling stage. The peculiar yellow and green mottling of the foliage is the first symptom. The upper surface of the leaf is wrinkled and its edges curled downward. The affected leaves are dwarfed and the fruit does not set properly. If the fruit is affected it shows alternate irregular yellow areas and warty green spots.

Cause—This is another of the so-called virus diseases. The virus which causes it is not carried over in the soil or in the seeds of the cucumber or other cultivated vegetables. It has been demonstrated, however, that it can live over the winter in the seed of the wild cucumber *(Echinocystis lobata* Torr. & Gray.) and in the perennial roots of the milkweed, pokeweed, ground cherry and catnip. Aphids and the striped and twelve-spotted cucumber beetle serve to transmit the virus from diseased to healthy plants. It may also be transferred by rubbing together healthy and diseased leaves until there is bruising, and by other methods in which the plant sap may be transferred from a diseased to a healthy vine.

Control—No entirely satisfactory control measures have been devised. All wild cucumber, milkweed, pokeweed, catnip and ground cherry within fifty yards of the greenhouses and cucumber fields should be destroyed if possible. Cucumber beetles and aphids should be controlled by dusting.

If infected plants are found in the crop early in the season they should be pulled up by the roots, carefully removed and burned. It does not appear to be worth while to destroy plants that become diseased after they are nearly full grown.



A—Cucumber leaf eight days after inoculation with *Phytomonas lachrymans*. The bacterial exudate has dried down into white crusts.

B—Cucumber leaf twelve days after spraying with *Phytomonas lachrymans*. Diseased tissue shrivelled and spots falling out.

C—Green cucumber fruit photographed six days after inoculation with *Phytomonas lachrymans*. There is an exudate at the point inoculated while the remainder of the fruit is sound.

D—Same as C, after twelve days; fruit ripening but still sound except at point of inoculation.

E—Section of green cucumber fruit ten days after inoculation. Tissue decayed only in vicinity of inoculation.

(After M. C. Bryan)

Powdery Mildew of Cucumbers

This mildew is seen on squash, cucumbers and melons. In Ontario it is seldom of any importance in the field, but it sometimes becomes troublesome on cucumbers grown under glass.

Symptoms—Circular powdery spots are seen on the leaves and young stems. At first the tissue of the spots remains normal but finally turns brown and dried. In severe attacks the leaves may be killed. If all the foliage of the vine is covered with mildew the plant is weakened, has a yellowish colour and most of the fruit is rendered useless.

Cause—*Erysiphe cichoracearum* D.C. is the name of the fungus causing this mildew. This fungus produces two kinds of spores, summer spores (conidia) which are produced in enormous quantities in chains on the surface of the leaves and which give to the spots their powdery appearance. These summer spores serve to spread the fungus during the growing season. The second form of spores known as ascospores are produced in little black fruiting bodies (perithecia) on the surface of the leaves and petioles. They serve to carry the fungus over from season to season.

**Control*—This mildew can be prevented by dusting with sulphur or spraying with Bordeaux at intervals of a week or ten days. Sulphur dust is most effective for combating powdery mildew in greenhouses. Sulphur dusting materials containing fifteen to twenty per cent. free sulphur are as effective as high grade dusts containing sixty to ninety-five per cent. free sulphur, and are safer, cheaper and therefore preferable. *E. F. Guba states that dust should be applied at the rate of about five to six pounds to a house 280 x 40 feet. Bordeaux mixture of the strength of one pound of copper sulphate, two pounds of hydrated lime and forty gallons of water can be safely used. Experiments have shown that if greenhouses are fumigated with hydrocyanic acid gas when Bordeaux is present on the leaves foliage injury may result.

Anthracnose of Cucumbers, Squash and Watermelons

This is a disease which is frequently seen in Ontario, especially on cucumbers. It is seldom serious in the field but occasionally becomes very severe on cucumbers grown under glass.

Symptoms—On the leaves of affected plants brown dead circular spots are seen. These are frequently very numerous so that the whole leaf is destroyed. On the stems elongated light brown areas are observed. On affected fruit, especially on the watermelon, water soaked sunken spots appear. These often have pink centres.

Cause—Anthracnose is caused by the fungus *Colletotrichum lagenarium* (Pass.) E. & H. This fungus remains alive in the old diseased tissue in the soil in the field or in the greenhouse. It is also known to be carried over in and on the seed.

Control—No satisfactory control measures have been discovered. As the fungus lives over at least one season in the diseased plant refuse left in the soil, a rotation of crops is essential. Seed treatment is also recommended. This consists of dipping the seed in corrosive sublimate (one ounce in six gallons of water) for five minutes then rinsing it thoroughly in running water and drying it. Spraying with Bordeaux mixture is also recommended. Spraying cucumbers under glass has not been profitable in

*"Control of Cucumber Powdery Mildew in Greenhouses," by E. F. Guba, Phytopathology, Volume 8, No. 10, October 1928.

the limited experiments carried on in this Province as the frequent and heavy sprayings required to control the disease have caused injury to the foliage and fruit.

Downy Mildew of Cucumbers

This disease is quite frequently seen in Ontario. It affects not only cucumbers but also squash, melons and pumpkins.

Symptoms—Irregularly shaped yellowish spots appear on the upper sides of the leaves. If a leaf is examined on the lower surface a downy fungus growth will be seen around the margin of the spots. If weather conditions are favourable these yellowish spots rapidly enlarge and finally the entire leaf withers up and dies.

Cause—Peronoplasmopora cubensis (B. & C.) Wint. is the fungus which causes this disease. This fungus spreads during the wet weather of the summer months by means of numerous spores produced on the under surface of the affected leaves. Just how this fungus passes the winter is not known. It is possible that it may survive the winter in greenhouses and spread to outdoor plants when the latter begin to grow. There is no evidence that it lives over in the soil outdoors.

Control—Spraying with Bordeaux mixture or dusting with copper-lime dust will control this disease. Begin spraying or dusting early. In comparatively dry weather apply the Bordeaux or dust every ten days. If, however, the weather is wet more frequent applications will be necessary. When the plants are young weak Bordeaux should be used (two pounds copper sulphate, three pounds hydrated lime and forty gallons of water). Later when the plants have formed runners the 4-5-40 formula can be used. In spraying or dusting it is important that both sides of the leaves should be covered with the fungicide. Frequent and heavy applications of Bordeaux applied to cucumber plants under glass may cause injury to foliage and fruit.

Downy Mildew of Muskmelon
(After F. C. Stewart)

LETTUCE

Lettuce Drop

This is a serious disease of lettuce. It is frequently seen in Ontario on lettuce grown under glass.

Symptoms—The first symptom usually observed is the wilting of the outer leaves which droop and fall flat on the ground. All the leaves of the plant are soon affected in the same way and in a few days the entire plant is dead and lying flat on the ground. This sudden and entire collapse of the plants has given rise to the name "Drop." The disease usually appears on the stem near the surface of the soil as a soft water-soaked spot that spreads downward until the roots are decayed and upward until the bases of the leaves are affected.

Cause—The most common cause of leaf drop is the fungus *Sclerotinia libertiana* Fckl. This fungus forms innumerable black hard bodies termed sclerotia. These are a resting stage of the fungus and they serve to carry it over from season to season.

Control—Soil sterilization is the most important control measure. Either steam or formaldehyde may be used (see pages 64 to 68). If a few diseased plants are seen in a bed they should be removed, taking care not to scatter any of the diseased tissue or sclerotia. After the plants are removed soak the vacant spot with a bluestone solution, one pound in six gallons of water. Keeping the top soil well stirred and as dry as good growth of lettuce will permit, helps to prevent the development of this disease. If possible a system of cropping should be so arranged as to alternate crops of lettuce with less susceptible vegetables such as radishes and tomatoes.

The London Leaf Lettuce Disease

This disease has caused much trouble to the growers of leaf lettuce under glass in the neighbourhood of London. It has also been observed to a lesser extent in greenhouses in other parts of the Province. Mr. F. B. Stewart, under the joint supervision of the Departments of Botany and Horticulture, made a careful study of this trouble, and it is from his report that the following account of it has been prepared.

Symptoms—The London Leaf Lettuce Disease is characterized by a number of striking symptoms. This disease usually appears in irregular patches here and there throughout the bed of lettuce. Quite often healthy plants may be found growing among diseased plants. In severe cases the entire crop is affected. The individual plants in a diseased bed of lettuce, nearing maturity, appear to be more distinct, whereas the plants in a healthy bed seem to blend into one another, making it difficult to pick out individual plants.

Usually the disease is first apparent by a general stunting about the second or third week after the plants are set out into the permanent beds. The growth of the plants seems to be at a standstill. After this delay they may begin to grow again, but in many cases are so badly checked that even at best they are far behind normal plants. These infected plants first become light-coloured. This is followed by a mottling of light yellow and dark green which becomes more pronounced as the plants grow older. Sometimes the young plants become infected before they are planted into the permanent beds. In this case the leaves usually become puckered and

distorted before the mottling of light yellow and green appears. The petioles of these plants usually become long and narrow. No further growth takes place except for the production of some small malformed twisted leaves. When plants become diseased late in their growth period the symptoms are less marked. It is often difficult to tell the diseased plants from healthy plants without using transmitted light. The leaves are only lightly mottled; the plants are somewhat stunted in most cases and are usually a little paler in colour but not enough to distinguish them from healthy plants.

Another important symptom by which this disease may be distinguished is by the appearance of the veins in the leaf. The veins in a diseased leaf are much more apparent and clear cut than those in a healthy leaf, and appear to be more numerous.

Cause—This lettuce disease is caused by one or more viruses, which are carried from diseased to healthy plants by two species of plant lice (aphids). The virus or viruses cannot be transmitted readily by mechanical means, that is, by touching diseased plants and then touching healthy plants, or by rubbing the juice from crushed, diseased plants on the leaves of healthy plants.

Control—Since aphids are probably solely responsible for the spread of this disease, control measures should be directed towards their elimination. It is believed that no lettuce plants for use in the greenhouse should be started outdoors, as in the open it is almost impossible to control aphids. Virus free plants can be secured by growing the young plants in the greenhouse. During August and early September the plants can be shaded from the sun. The young plants as soon as they appear above the ground should be dusted with a three per cent. nicotine lime dust and dusted every week thereafter until they are nearly mature (two or three weeks before harvesting), or the greenhouse should be fumigated each week with a commercial tobacco preparation, used according to the directions on the can.

Downy Mildew of Lettuce

This mildew is very often found in Ontario on lettuce both in the field and under glass. It seldom causes much damage to field or garden lettuce, but sometimes injures lettuce grown under glass very severely. There is a great difference in the susceptibility of varieties of lettuce to Downy Mildew. Some varieties are much more susceptible than others. New York head lettuce is extremely susceptible. Big Boston and Hanson are reported as being resistant.

Symptoms—Yellow spots are observed first on the older foliage. These yellow spots or blotches are seen on the upper surface of the leaves which turn brown at the margin and fall. On the lower surface of the blotches a delicate white fungus may be seen. As the margins of the leaves often turn brown some growers call this disease Brown Margins. If young lettuce is severely attacked the plants are dwarfed, yellowed and useless for market purposes. Lettuce which is slightly affected by mildew is very likely to soft rot in transit and storage. This is one reason why growers have to be careful to guard against it.

Cause—Downy Mildew of lettuce is caused by the fungus *Bremia lactucae* Reg. This fungus is spread by means of numerous spores produced on the lower surface of the affected leaves. It is able to live in the soil of the beds for a considerable length of time but cannot withstand

freezing and thawing. Outside it lives over winter on wild lettuce which grows as a winter annual. The plants are infected in the fall and the fungus remains dormant in them until spring. In the greenhouse the fungus thrives best and causes most trouble when the difference between day and night temperatures is greatest and when the days are most cloudy.

Control—This mildew can be prevented to a very large extent by proper handling of the lettuce crop grown under glass. Light and air are important factors. The houses should be constructed so that plenty of air and sunlight are available. Temperature is also an important factor, and if this mildew is troublesome the houses should be kept three or four degrees higher at night than is recommended under normal conditions. The plants should be watered so as to wet the foliage as little as possible. As young plants are most susceptible it is recommended to spray them before transplanting with Bordeaux mixture (three pounds bluestone, four pounds hydrated lime, and forty gallons of water). The first spraying should be given several days before the seedlings are ready to be transplanted, and a second application should be given two or three days before they are transplanted. If the plants are properly handled subsequently, these two sprayings will protect them against mildew. Renewing the soil in the beds or sterilizing it with steam or formalin also aid in the control of this and other lettuce diseases.

Bacterial Diseases of Lettuce

These diseases are considered as a group because their general symptoms may be similar, and because it is sometimes difficult to distinguish one from another. They are the cause of considerable loss to lettuce growers; losses range from five to eighty-five per cent. in both greenhouse and field crops. Furthermore, the same general unfavourable conditions under which the plants may be grown are inducive to each of the diseases. Under glass these are a stagnant, humid, warm atmosphere, excessive watering and poor ventilation; in the field the contributing factors are, addition to the soil of manure or compost that is incompletely rotted, and prolonged periods of warmth with high humidity.

Bacterial Rot of Lettuce

Symptoms—The marked symptoms of this disease are the numerous spots on the leaves which at first have a water-soaked appearance. As these spots increase in size they fuse to form large blotches which eventually spread over the entire leaf. Such leaves turn brown and rot, sometimes with a soft, wet rot and sometimes with a dry rot and shrivelled leaves. The heart of the lettuce may be sound while the outer leaves are soft-rotted or shrivelled and dry, and the leaves between more or less affected.

Cause—This disease is caused by the bacterial organism, *Phytomonas viridilivida* (Brown), Bergey et al.

Control—Levine found that spraying with formalin, one pint to thirty gallons of water, would check the disease.

Marginal Leaf Blight of Lettuce

Symptoms—The chief symptoms of this disease are the brownish, dry and papery margins of affected leaves, which accounts for this trouble being mistaken for Tip-burn. The edges affected first show a slight marginal wilting, then turn brown or blackish over an area almost a quarter

of an inch in depth along the entire edge of the blade. If the season is dry the margin of the leaf may fall away leaving a jagged edge.

Cause—*Phytomonas marginale* (Brown) Bergey et al, is the bacterial organism which causes this disease. The bacteria enter the plant through the breathing pores of the leaf (stomata) during periods of high humidity, cold, or when plants are excessively watered.

Control—Subirrigation instead of overhead watering is a safeguard. Under glass good ventilation will almost, if not entirely, prevent the disease.

Bacterial Wilt of Lettuce

Symptoms—The chief symptom of this disease is a wilting of the plant. In the early stages of the disease the infected plants are lighter green in colour than healthy ones. The oldest leaves are usually affected first. This is followed by infection of the younger leaves, stems and roots, or the stem may be diseased while the leaves remain apparently healthy. Brown spots may occur on the leaves which at first are definitely outlined, but later these coalesce to form darkened blotches. Diseased plants are not firm in the ground because the roots are diseased. In some instances wilting of the whole plant may take place without any spots appearing on the leaves.

Cause—This disease is caused by the bacterial organism *Phytomonas vitians* (Brown) Bergey et al.

Control—Use thoroughly decomposed compost or well rotted stable manure.

Tip-Burn of Lettuce

This is one of the most destructive diseases with which lettuce growers have to contend. It usually does most damage in seasons when the crop develops so rapidly that it is impossible to cut it all just at the right time.

Symptoms—The symptoms are very characteristic. On affected plants the edges of the leaves die and turn brown thus making the lettuce unsightly and hence not readily saleable. In severe cases the growth of the plant is interfered with. Hard headed varieties of lettuce are usually more susceptible to tip-burn than the loose heading and leafy varieties.

Cause—It is generally conceded that tip-burn is caused by weather conditions, chief of which is high temperature. Formerly it was thought to be brought about by two or three warm days resulting in soft watery growth followed by a warm bright day with rapid evaporation, but it has been shown that tip-burn can originate even in the dark and it is now thought that the degeneration of the cells at the tips of the leaves is due to faulty respiration, which is brought about by high temperature.

Control—Little exact information is available concerning the control of this disease. Lettuce grown under glass should not be overwatered and the house should be well ventilated and kept comparatively cool. In the field when the soil is packed by heavy rains deep and frequent cultivation is recommended. Big Boston head lettuce is very susceptible to tip-burn. In experiments conducted in the United States the sparing use of potash and medium applications of phosphate have reduced the amount of tip-burn in some fields.

ONIONS

Onion Smut

This is the most destructive disease of onions. It has become prevalent and very destructive in several of the important onion growing districts in Ontario.

Symptoms—Smut develops only on onions that are grown from seed in soil containing smut spores. It frequently destroys large numbers of the seedlings soon after they appear above the ground. The leaves of affected seedlings become curled and twisted, and dark streaks show within the tissues. These streaks are filled with a dark brown powdery mass. Diseased seedlings that are not killed in the early stages often die later or produce small, distorted bulbs with black streaks. If these black streaks are broken open they are found to be filled with a black mass of smut spores.

Cause—Onion Smut is caused by the fungus *Urocystis cepulae* Frost. This is a soil organism that may live in the ground for many years. It can infect onions only for a brief time during the development of the seedlings. The period of infection extends from the time of germination until the seedlings are in the first leaf. This is usually about two weeks. Once the seedlings have passed this stage the fungus cannot infect them. The spores of the fungus are carried from place to place on onion sets, by running water or in the soil adhering to implements, the feet of men and animals and the roots of other vegetables.

Control—A formalin solution applied when the onion seed is being sown has given excellent results in the control of this disease. The formalin is applied by means of a tank and drip attachment on the onion seeder. Numerous experiments have been conducted in the Pelee marshes on muck soil and the best results have been obtained from the following solutions: (1) Formalin, one pint to fifteen gallons of water, applied at the rate of 150 gallons per acre; (2) Formalin, one pint to ten gallons of water, applied at the rate of 100 gallons per acre. The latter solution cuts down to a minimum the amount of water that must be used and thus reduces the labour to a considerable extent. This is an important factor. Loam soils do not require as much liquid as muck soils.

The formalin method for smut control is now extensively used by commercial onion growers and it is the only satisfactory treatment when large quantities of onions are grown. Those who wish to grow a few onions in soil containing smut may do so by sowing the seed in smut-free soil and then transplanting the onions after they have passed the susceptible stage. Onion sets may be planted in soil containing smut and not develop the disease, that is, provided the seed from which they were grown was sown in smut-free soil. Sets grown from seed in smutty soil is one of the methods of distributing the disease.

Onion Blight or Downy Mildew

This is a very common disease of the onion in Ontario, and in some parts of the Province it frequently decreases very materially the onion crop by destroying the leaves and thus reducing to a marked extent the size of the bulbs.

Symptoms—The disease is usually first noticed in late June or July. Affected leaves show peculiar violet-tinted areas which are due to the fuzzy spore-bearing portions of the fungus on the surface. They very soon

become pale or yellowish in spots, collapse and break down. In severe attacks all the leaves are soon destroyed. Often a new crop of leaves develops and these also may be destroyed by the disease. From this second attack the onions seldom recover.

Cause—This disease is caused by the fungus *Peronospora schleideni* Unger. Two kinds of spores are produced by this fungus, namely, thin-walled summer spores borne on the minute, branched spore-bearing part of the fungus covering the surface of the attacked leaves, and thick-walled resting spores (oospores) formed in the tissues of the dead leaves. The summer spores are freely scattered by wind during the summer and new leaves become infected. In this way the disease is spread very rapidly, especially during damp, muggy weather. Dead leaves containing the thick-walled resting spores lie on the ground during the winter and in the spring these spores germinate and give rise to the disease if onions are planted on the same ground again. The fungus also lives over as dormant fungus threads (mycelium) in the onion bulbs and sets.

Control—Rake up and burn the diseased tops as by so doing many of the resting spores will be destroyed. If possible practice a rotation of crops as the fungus is carried over the winter by the resting spores in the soil, and it is believed that they retain their vitality for two or three years. The choice of land for the growing of onions is important. The soil should be well drained and wind barriers such as woods, hills, fences and weeds should be avoided as far as possible, so that there will be a free circulation of air over the field which will dry the plants quickly after rain and heavy dew. When growing onions from sets or planting seed bulbs it is important that these should not be taken from fields where onion blight has been prevalent. Spraying with Bordeaux with a sticker has been recommended by some American authorities. At best it is a difficult task and so far there is not experimental evidence to show that it is profitable here in Ontario. However, in those sections of the Province where onion blight causes serious loss nearly every year, spraying in conjunction with the other methods of control should be given a fair trial. Spray with Bordeaux mixture, four pounds bluestone, five pounds hydrated lime and forty gallons of water. To this mixture add three pounds of resin fish oil soap as a sticker. The spraying should be started if the weather becomes wet towards the end of June and an application made at least once a week if it is a wet season. In order to avoid destroying the onion plants the sprayer (if a power outfit) should be equipped with a very long boom and many nozzles, or with two or more leads of hose so that a man at the end of each hose may spray three or four or more rows at a time.

Onion Smudge

This is a disease that is common in Ontario. In wet seasons it seriously disfigures white onions. It does little or no harm to yellow or red onions.

Symptoms—The most pronounced symptom is the dark green or black smudge on the bulb or neck of the onion. Sometimes the surface of the smudge spots is uniformly black. Frequently, however, the black smudging is in concentric circles. The smudging may be so extensive as to cover the greater portion of the bulb and disfigure it very badly. In severe cases the fungus grows through the outer scales into the living tissue below, causing collapse of the fleshy scales. The disease may appear at any time in the life of the onion plant in storage or during transportation as well

as in the field. Sometimes it causes a damping off of the seedlings. This symptom of the disease has not been observed in Ontario.

Cause—This disease is caused by the fungus *Colletotrichum circizans* (Berk.) Vogl. This fungus passes the winter on onions, on sets and in the soil. It is only under the most favourable conditions of moisture and temperature that it can attack growing onions and cause disease. It is carried long distances on bulbs and sets, and possibly on the seed. Most of the infection takes place in the field. This fungus develops best in relatively high temperatures (75 to 80° F.) and requires relatively high soil moisture. It causes most damage when we have hot damp weather shortly before harvest time.

Control—No entirely satisfactory control measures are known. Careful harvesting of the bulbs and thorough drying before placing in storage help to reduce the injury caused by this disease. Practicing a rotation of crops so that white onions are not grown on the same piece of land oftener than once in every three or four years should reduce the loss from this trouble. This disease can be avoided by growing the resistant coloured onions in place of the white or silver-skinned varieties.

PEAS

Root Rot and Blight

In the eastern section of Ontario, especially in Prince Edward County and adjacent mainland, this disease has been a serious handicap for many years. Some men have been forced to give up pea growing or to abandon the crop for several years. In many cases, tenants have suffered heavy losses through sowing peas on "pea sick" soil.

Dr. R. E. Stone, of the Botanical Department, has made a special study of this disease and the following account of it is based on his observations and experiments.

Symptoms—The disease generally becomes noticeable just about the time the peas are coming into bloom, although in severe cases it may be noticed earlier than this. Frequently large patches in fields or even whole fields of peas will dry up and produce little or no seed. First the lower leaves turn white or grey and in a few days or a week the plants wilt down. The roots of such plants are usually brown and rotten. The outer layers, or cortex, slough off readily and the little feeding roots are all destroyed. On the stem, just at the surface of the ground, there is generally a blackened area. The whole top of the plant takes on a dry, greyish colour.

Cause—This disease appears to be caused by at least two fungi growing on the roots, a species of Fusarium and *Aphanomyces euteiches*, Dreschler. These are soil fungi, that is, they are capable of living in the soil for a considerable period of time.

Control—First, crop rotation; second, the use of resistant varieties. If the disease has been serious, a rotation of crops should be followed in which peas are not grown in the field oftener than once in five years.

Resistant varieties. Experiments carried on over a number of years have shown that the following varieties of peas are resistant to root rot and blight and can be grown safely in infested soil: Alcross, Alderman, Champion of England, Green Admiral, Green Feast (Lincoln), Improved Advancer, Horal, Prince of Wales, Quite Content, Rice's 330, Telephone, Yellow Admiral.

The following varieties are susceptible and cannot be grown in infested fields: American Wonder, Alaska, Earliest of All, Gradus, Horsford, Improved Stratagem, Laxtonian, Laxton's Progress, Little Marvel, Nott's Excelsior, Onward, Peter Pan, Roger's Winner, Sutton's Aquisition, Thomas Laxton.

Blight, Leaf Spot or Pod Spot of Peas

This disease is commonly seen in Ontario but seldom causes enough injury to attract attention.

Symptoms—Stems, leaves, pods and seeds are affected. Stems of infected plants show discoloured areas of dead tissue, sometimes extending completely around them, destroying the shoot. Diseased leaves show circular or oval discoloured spots from one-eighth to one-half inch in diameter. On the pods light coloured, sunken spots develop much like those of bean anthracnose.

Cause—This disease is caused by the fungus *Mycosphaerella pinodes* (Berk. and Blox.) Stone. This fungus passes the winter chiefly as dormant fungus threads (mycelium) in the seeds.

Control—So far it has not been necessary to practice any particular control measures in Ontario. If it should become serious it can be checked by the following measures: Sow non-infected seed. If only a small amount of seed is necessary, disease free seed can be obtained by selecting it from healthy pods. Large quantities of non-infected seed can be secured from seed growers in the dry regions of the West. Grow peas on well drained soil and practice a rotation of crops. Do not use pea straw or other pea refuse as a fertilizer on fields where peas are to be grown. No varieties of peas are immune but Horal and Champion of England are very resistant to this disease as well as to Root Rot and Blight.

Bacterial Wilt or Stem Blight of Field and Garden Peas

Symptoms—This disease can be recognized readily by watery, olive-green to olive-brown spots and streaks on stems, petioles, leaves, stipules and pods. When the disease makes its appearance early in the season, before the plants are more than three to four inches high, one usually finds a very uneven stand with several feet of the rows without a plant, but on close examination of the ground one will find the brown withered remains of the plants. Stem spots are more linear than the water-soaked spots on the leaves, and sometimes the whole stem turns dark green and finally brown. Infection may spread through the flower stalk, killing the flower and causing the young pods to shrivel and decay. Older pods show water-soaked spots and cracking, and from these spots the seeds inside become infected and covered with bacterial slime, which may remain on the surface or may penetrate the seed coat. The bacteria may break down the tissue to produce large cavities, and if they enter the veins wilting of the plant results.

Cause—This disease is caused by the bacterium *Phytomonas pisi* (Sackett) Bergey et al, which is carried over on the seed and in the soil, and enters the plant through the breathing pores (stomata) or through wounds.

Control—As the organism is seed borne, endeavour to use seed from crops which are known to be free from the disease. Practice a rotation of crops so that peas are not grown on the same soil oftener than once in three or four years.

POTATOES

Late Blight and Rot of Potatoes

This is the most destructive disease of potatoes in the Province. In wet seasons it frequently destroys a large proportion of the crop. The effects of the disease are not noticed usually until late summer—August or September. Occasionally, however, if the weather is wet about the middle of July the disease may be observed in the fields by the middle or end of the month. It is always worse on low lands and on the heavier types of soils.

Symptoms—This disease, as the name implies, causes a blighting of the leaves and a rotting of the tubers. The blight is seen usually first on the margins of the lower leaves. Irregular dark spots or blotches are observed. These have a water-soaked appearance when held up to the light. On the under surface of these blotches especially around the margin a delicate white fungus growth may frequently be seen. In wet weather the blotches enlarge rapidly and the whole leaf is involved, becomes soft, brown, rotten and droops. In this way all the tops may be destroyed in a few days. If dry weather checks the development of the disease the spots do not enlarge but become dry, brittle and brown. On some of the infected tubers pits or more or less depressed areas are seen. Sometimes these have a somewhat purplish or reddish tinge and a water-soaked appearance. If the diseased potatoes are cut, a rusty brown dry rot is seen in the flesh

Late Blight.

Early Blight.

just beneath the skin. Infected tubers dry rot in the field or in storage. Tubers when dug may show no signs of rot, but if they have been produced by blighted plants the rot is very likely to develop in about three weeks after they are placed in storage. A wet soft rot often develops in wet seasons. This is frequently seen when the potatoes are dug and is due to secondary organisms which gain entrance to the tubers through the dead areas produced by the fungus which causes the Late Blight and Rot.

Cause—Late Blight and Rot is caused by the fungus *Phytophthora infestans* (Mont.) De Bary. This fungus is rapidly spread through the crop during wet weather by means of numerous spores produced on the lower surface of the affected leaves and scattered by rain, wind and insects. Some of these spores are washed off the leaves down through the soil on to the tubers which they are able to infect. Tubers are also often infected by coming in contact with blighted tops and contaminated surface soil when they are being dug. The fungus is carried over the winter chiefly as fungus threads (mycelium) within infected tubers. Slightly infected tubers show little or no external evidence of the disease. When infected tubers are used for seed the fungus threads in them may develop and produce spores on the surface of the seed pieces, or the fungus threads may grow up into the sprouts and produce spores on the outer surface of the growing shoots. The spores produced on the seed pieces or on the developing shoots may be washed or splashed by rain to the leaves which they are able to infect. These infected leaves soon develop blight. There is also some evidence to indicate that the fungus may be carried over as resting spores in the diseased tops. This, however, has not been demonstrated in Ontario. The conditions which favour the development of this fungus are excessive moisture, cool nights and warm days.

Characteristic Rot due to the Late Blight and Rot fungus.
(After Gussow)

Control—Spraying with Bordeaux mixture is the most reliable means of preventing Late Blight and Rot. Commence spraying when the potato beetle eggs are just hatching, which will usually be when the potato plants are from five to eight inches high, and keep the foliage covered with Bordeaux throughout the season, taking special precautions to see that it is well covered during wet weather. Do not put off spraying because it looks like rain for once dry the spray mixture will remain on the leaves and be

on at the critical time. This statement will be understood when it is realized that infection takes place during or immediately after rain. For the first application use Bordeaux mixture (formula four pounds copper sulphate, five pounds hydrated lime and forty gallons of water). Add two pounds of arsenate of lime (calcium arsenate) to each forty gallons. Repeat the spraying often enough to keep the foliage well covered. Add the arsenate of lime to the Bordeaux only when required for potato beetles. No stated number of sprayings with the Bordeaux can be recommended; the number depends on the weather—the wetter the weather the larger the number. Four to seven sprayings are often necessary. If the season is favourable for Blight and Rot continue the spraying until the plants have finished their growth and died or have been destroyed by frost. It is very important to use plenty of Bordeaux at each application. Forty gallons may be sufficient to cover an acre of potatoes when the plants are small but when the plants are large from eighty to one hundred gallons or more may be required for each acre. The best results are obtained by applying the Bordeaux under high pressure in the form of a fine mist so as to cover both surfaces of the leaves. High pressure power sprayers which deliver plenty of the Bordeaux to cover thoroughly the vines are the most satisfactory machines for spraying.

Dusting is sometimes practised instead of spraying. Copper-lime dust is used. On the whole the results from dusting have not been as satisfactory as those from spraying. Some growers, however, prefer dusting to spraying because it requires less time. The best results from dusting are obtained from frequent and heavy applications of the copper-lime dust.

Other means which can be used to lessen loss from this disease: Plant the more rot resistant varieties of potatoes (see O.A.C. bulletin 239). Avoid soils that are not thoroughly underdrained either naturally or artificially. Plant certified seed potatoes. These are potatoes known to be comparatively free from disease. When the vines are blighted allow them to die and become thoroughly dry before digging the potatoes. Remove the potatoes from the field as soon after digging as possible. Sort them carefully and store in a cool, dry cellar, spreading out as thinly as possible. The proper temperature for storage is about 38° F.

Early Blight

This disease is common and in some years causes noticeable damage. It sometimes appears when the plants are small but it is most abundant about the time the potatoes are in blossom. In severe cases the foliage is badly damaged and the tubers remain small. Unhealthy plants and those attacked by the flea beetle suffer most from this disease.

Symptoms—Small, scattered, greyish-brown circular spots are first observed on the leaves. These take on a minutely velvety appearance and gradually become larger. Sometimes they run into one another until in some cases half the leaf may become brown and curled. As the spots enlarge faint concentric rings appear on them described as "target brand" markings. Leaves which are very badly spotted often turn sickly yellow in colour.

Cause—The causal fungus is *Macrosporium solani* E & M. This fungus is carried over the winter by means of spores in the soil and by fungus threads in diseased potato tops and weeds.

Control—Spray with Bordeaux mixture as directed for Late Blight and Rot. Take special care to see that the early applications are very

thoroughly applied. A three to five year rotation of crops will also help control this disease. Weeds closely related to the potato such as nightshade and ground cherry should be destroyed as they harbour the causal fungus.

Common Scab

This scab is familiar to nearly every potato grower. It is, however, not confined to the potato but is sometimes seen on garden beets, sugar beets, turnips and radishes.

Symptoms—It is easily recognized by the roughened corky spots on the skin of the tubers. These may be few and scattered or numerous and close together so as to disfigure the potatoes badly. Sometimes there are also blackened pocket-like cavities. Scab does not injure the flesh of the tubers to any great extent but it renders them unsightly and hence not readily saleable when potatoes are plentiful.

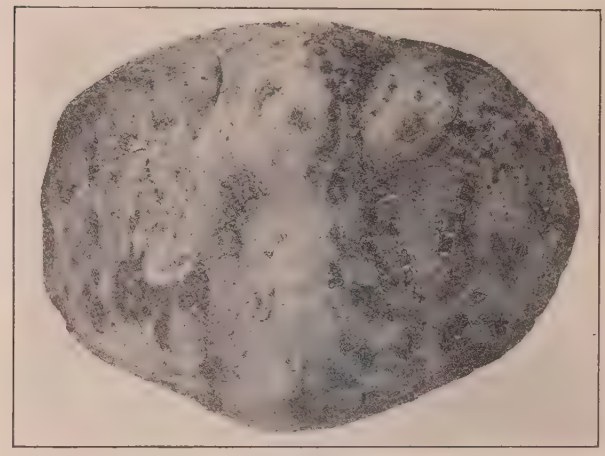
Cause—Common scab is caused by one of the higher bacteria known as *Actinomyces scabies* (Thax.) Gussow. This organism is carried over the winter on seed potatoes and in the soil. It remains in the soil for several years after a crop of scabby potatoes has been produced. It will also pass through the intestines of stock fed on scabby potatoes. This organism appears to be native to some soils. A few scabby potatoes in a bag may contaminate the whole lot. It thrives best in an alkali soil and is checked by acidity. It develops most readily in a soil rich in organic matter and at a comparatively high temperature.

Control—This disease can be controlled only by combining seed treatment with cultural practices. Seed treatment alone cannot be relied upon. Its chief purpose is to prevent the introduction of the scab organism into non-infected soils. It will not appreciably reduce the amount of scab in soils in which the scab organism is abundant. The cultural practices which can be employed to control potato scab are as follow: Use seed potatoes free from scab. Practise a definite rotation of crops in order to starve out the organism in soils heavily infested with scab. Beets, mangels and turnips should not be grown in such a rotation as they serve as carriers for the scab organism from season to season. Under normal conditions practise a rotation of from three to five years between potato crops. If the soil is very heavily infested with the scab organism it may be necessary to follow a five to six year rotation. Grasses, small grains, alfalfa or clover, constitute excellent crops for such rotations. Plant potatoes immediately following clover, alfalfa and other leguminous crops. Be careful in the use of fertilizers. Lime, wood ashes and fresh stable manure should not be applied to soils intended for potatoes on account of their alkaline nature. *A suitable fertilizer for scab infested soils consists of 267 pounds nitrate of soda, 200 pounds sulphate of ammonia, 1000 pounds 16 per cent. super phosphate, 333 pounds sulphate of potash magnesia, 200 pounds muriate of potash which is equal to a ton of 4-8-10 mixture. This should be applied at the rate of 500 pounds to 1000 pounds per acre on normally good potato soil. Never feed potatoes infected with scab and peelings from same to stock unless they have been boiled. Treat seed potatoes with formalin or mercuric chloride. (See pages 42 and 43.)

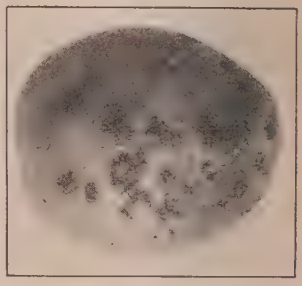
*Recommendations regarding fertilizer made by Professor Bell, Ontario Agricultural College, Guelph.

Powdery Scab

This disease was first reported as occurring in Canada about 1912. It was found in Prince Edward Island, Nova Scotia, New Brunswick,



Powdery Scab (after Morse).



Common Scab. (Original.)

Quebec and Alberta. In 1914 it was reported from Northern Ontario. It does not seem to be established in the southern parts of the Province. It does not appear to cause serious trouble in warm, comparatively dry soils.

Symptoms—Tubers infected by the Powdery Scab fungus become covered with conspicuous scab spots which are more clearly defined, more elevated and smoother on the surface than Common Potato Scab. When the skin of the scab spot is broken the cavity beneath is seen to be filled with a brownish or greenish powder. The chief injury is the unsightly appearance of the tubers. In very severe cases, however, the potatoes may be stunted and malformed and there is always a greater tendency for infected tubers to shrivel and dry rot in storage.

Cause—The cause of Powdery Scab is a slime mould known as *Spongospora subterranea* (Wallroth) Johnson. This fungus is spread mainly on seed potatoes. It is introduced into new localities chiefly through planting "seed" which is infected or which has come in contact with infected tubers or with bags, crates, implements, etc., which have been used in handling them. Once the fungus gains entrance to a soil it will apparently remain there for a number of years. It develops best in wet cool soils and it will not develop in warm, comparatively dry soils.

Control—Secure seed potatoes from a district known to be free from Powdery Scab. Plant only sound tubers free from scab and as a precaution disinfect them with either corrosive sublimate or formalin. (See directions pages 42, 43.) Good drainage and a long rotation of crops will also aid in the control of this disease.

Rhizoctonia or Black Scurf

This disease is very frequently met with in Ontario, and in seasons of excessive rainfall often results in a noticeable reduction of the crop. It does more damage in Northern Ontario than it does in the southern parts of the Province.

Symptoms—Tubers are very frequently seen with what appear to be lumps of hardened soil adhering to them. These are black in colour when wet. They vary in size from mere specks to one-quarter of an inch in diameter. Sometimes they are very numerous and quite noticeable. They are known as sclerotia and consist of compact masses of resting fungus threads (mycelium). The skin of the potato beneath them is often roughened and russeted but the flesh of the tuber is not injured to any appreciable extent. If potatoes, however, with these sclerotia adhering to them are planted the fungus may spread into the developing sprouts and kill them before they get above the ground. This is one cause of "misses" in the rows. Later in the season several other symptoms may develop. Young shoots may wither and die and if they are pulled up and examined there will be found near the base of the stems brown dead areas often encircling them. Sometimes large plants become sickly yellow and develop many fine spindly shoots. Such plants also show dead brown areas near the base of the stems and on the underground parts. Occasionally at the base of the stems of affected plants clusters of small tubers may be found and quite frequently small greenish potatoes are seen on the stem above the ground. Such aerial tubers are very characteristic of the disease but they may result from other causes such as injury to the stem by cultivation.

Cause—This disease is caused by the fungus *Corticium vagum* B. and C. This fungus attacks many plants besides the potato. Among the more important hosts of this fungus are carrots, beets, beans, cabbage, parsnips, onions, turnips, peas, celery, rhubarb, spinach and lettuce. The fungus lives over winter in the soil and on the tubers in the form of fungus threads (mycelium) and sclerotia. It is probable that few soils are free from it.

Control—Dig the potatoes as soon after they are mature as possible. The longer they are in the soil, especially in a wet fall, the greater the chances of sclerotia developing on them. Select seed potatoes as free as possible from little, black, hard lumps (sclerotia) on the surface and disinfect them, before they are cut for planting, with corrosive sublimate or acid corrosive sublimate. See directions on page 42. This treatment should be done when the potatoes are dormant, that is, before the buds in the eyes begin to grow.

Hard black lumps (sclerotia) of Rhizoctonia on Potato.
(Original.)

Methods of Disinfecting Seed Potatoes

Disinfecting seed potatoes helps in the control of such diseases as Blackleg, Common Scab, Black Scurf or Rhizoctonia and Powdery Scab. They should always be treated before they are cut and if possible before they have started to sprout, as the treatment destroys the sprouts and thus retards the growth.

A convenient method for handling potatoes when treating them is to place wooden barrels on a sloping elevated platform in such a manner that the solution used for treatment can be drained off from the bottom of one barrel before removing the potatoes, and added to another barrel.

All bags and crates that will be used to handle treated potatoes should be disinfected also with formalin (one pint to thirty gallons of water) or corrosive sublimate (mercuric chloride) but not with any liquid containing acid as the acid will destroy them. Corrosive sublimate corrodes metal and hence should be handled in wooden or earthen containers. It is also very poisonous, and bags disinfected with it should not be used to hold potatoes intended for food unless they have been well washed in water to remove any of the poison that may adhere to them.

There are many methods of disinfecting seed potatoes. Four of the most effective are described below.

The Acid Corrosive Sublimate Treatment

(This treatment is recommended for the control of Black Scurf or Rhizoctonia, Blackleg, Common and Powdery Scab)

It consists of dipping the seed potatoes before they are cut, for ten minutes, in a solution made by stirring four ounces of corrosive sublimate (mercuric chloride) in two pints of commercial hydrochloric acid and diluting to twenty-five gallons with water. This solution may safely be used for ten treatments, and if the duration of dipping is increased to fifteen minutes for a further five. The potatoes should be immersed unbagged, and afterwards dried. The treatment may be carried out some months before planting. This is a cheap and effective method.

N.B.—If this treatment is used, be sure to dry the potatoes immediately afterwards. Corrosive sublimate is a deadly poison and should be kept out of the way of children and stock. Potatoes disinfected with it should never be used for food for man or beast. It corrodes metal and should be handled in wooden or earthen vessels.

Corrosive Sublimate Treatment

(This treatment is recommended for the control of Black Scurf or Rhizoctonia, Blackleg, Common and Powdery Scab.)

If a large tank or trough is available, soak the seed potatoes in clean water for five to ten hours. If no large tank is available place the potatoes to be treated in a pile on the barn floor, sprinkle them thoroughly with water and cover them with wet sacks, and leave for twelve hours. At the end of this time soak them for an hour and a half in a solution of corrosive sublimate of the strength of four ounces of corrosive sublimate in twenty-five gallons of water. In preparing this solution, dissolve the corrosive sublimate in a little hot water, then add it to twenty-five gallons of cold water. Fill a barrel or trough with the potatoes, then add the solution until the potatoes are covered. Leave for the required time, then drain off

the solution into another receptacle. After each lot of tubers has been treated, add half an ounce of corrosive sublimate and keep the volume of the solution constant by adding more water when necessary. After four lots of tubers have been treated the solution should be entirely renewed.

Formalin or Formaldehyde Treatment

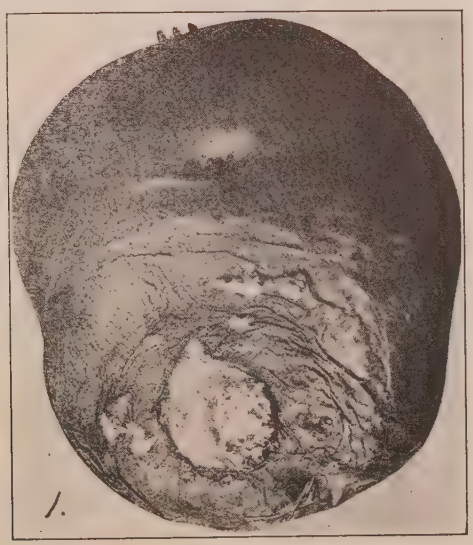
(This treatment is recommended for the control of Common Scab only.)

Soak the seed potatoes before they are cut for two hours in a solution, made by adding one pint of commercial formalin to thirty gallons of water. The same formalin solution can be used to treat successive lots of potatoes. Thirty gallons of water is sufficient to treat from forty to fifty bushels if ordinary precautions are taken not to waste the solution when dipping. If the potatoes are not all disinfected on the same day, it is advisable to make up a fresh supply of formalin for each day's treatment. Formalin does not affect metal hence galvanized or tin pails may be used.

Hot Formaldehyde Treatment

(This treatment is recommended for the control of Common Scab and Black Scurf or Rhizoctonia.)

A formalin solution consisting of two pints of formalin in twenty-five gallons of water should be kept at temperatures ranging from 120° to 126° F. and the potatoes to be treated should be soaked in this solution for three minutes. After immersion the tubers should be placed in a pile and covered with blankets, bags or other covers for at least an hour in order to retain the volatile formaldehyde around the tubers. After the covers are removed the tubers should be allowed to dry thoroughly. It is also important to disinfect all bags and crates that are used in handling the disinfected potatoes. Seed disinfection should be done when the tubers are dormant or nearly so. It can be done in the fall, or in the spring immediately before planting.



Fusarium Dry Rot of Potatoes. (Original.)

Fusarium Dry Rot

This rot frequently develops in potatoes in storage late in the winter or early spring.

Symptoms—A firm, cheesy, dry rot develops in the tubers. This is often confined more or less to one end of the potato. The surface of the rotten portion is often covered with a white or pinkish fungus growth. Sometimes the whole potato shrivels and dries to a hard mass.

Cause—Various species of Fusarium are the chief cause of this trouble. Some of these gain entrance to the tuber if the skin is broken when the potatoes are being harvested, transported or stored.

Control—Handle the potatoes in such a way as to eliminate bruising as much as possible.

Potato Canker or Wart Disease of Potatoes

This disease was found in Canada in 1912, but is not found in this country at the present time. This is owing to the fact that at its first appearance very prompt measures were taken to stamp it out, and prob-

Potato Canker. (After Gussow.)

ably to some extent to the fact that the two commercial varieties of potatoes which are so extensively grown in Ontario, namely, Green Mountain and Irish Cobbler, are immune to this disease. It is a very serious disease to susceptible varieties of potatoes, and it is important therefore that

Ontario growers should be able to recognize it in order that they may report its presence promptly should it at any time appear in their crop.

Symptoms—Potato Canker is not usually observed until harvest time. Badly affected tubers are simply brownish-black masses of warty excrescences not in the least resembling potatoes. Tubers showing the early stages of the disease have some of the eyes slightly protruding and composed of simple or compound groups of small brown nodules. In the early stages this disease is very likely to be overlooked by the casual observer.

Cause—This disease is caused by the fungus *Synchytrium endobioticum* (Schilb) Perc. This organism is carried over from season to season in the soil or in tubers. It may be carried into clean soil by drainage from infested soil, by farm implements and on the feet of men and animals. Planting infected tubers or tubers which have come in contact with diseased tubers is another way by which this organism is spread. It is also spread in manure from animals to which diseased potatoes have been fed and by garbage into which warts or peelings from diseased tubers have been thrown.

Control—Grow varieties of potatoes known to be immune to Potato Canker. In tests conducted in the United States the following varieties have been found to be immune: Green Mountain, Irish Cobbler, Early Petoskey, Peach Blow, McCormack and Burbank. Among those valuable varieties which were found to be very susceptible to Potato Canker are: Rural New Yorker, Early Rose and American Giant. If susceptible varieties of potatoes are grown be on the watch for this disease and if suspected potatoes are found send samples to the Dominion Botanist, Central Experimental Farm, Ottawa, or to the Botanical Department, Ontario Agricultural College, Guelph.

Plant in middle showing typical Leaf Roll. A healthy plant on either side for comparison.

Black Leg of Potato.

Leaf Roll

In the past this disease has been very prevalent in the potato growing districts of Old Ontario. Since the use of certified seed potatoes has become general, very much less leaf roll is seen in the Province. This disease may reduce the yield to a very marked extent.

Symptoms—These are very variable. Affected plants are always more or less dwarfed and in some varieties the leaves assume a characteristic upright, almost staring habit instead of drooping over in the normal way. This symptom is sometimes absent, and instead the plants present a low-headed bushy appearance. When the crop is badly affected the poor growth of the foliage is very noticeable. It is practically never as green on affected plants as on healthy ones, and occasionally on certain varieties it takes on a purplish or reddish colour at the tips and around the margins of the leaves. Rolling of the lower leaves is always associated with the disease. The rolling is often rather inconspicuous and may not extend beyond the leaves lying close to the ground although it may affect the intermediate and even the topmost leaves. Marked rolling of the upper leaves, however, is often seen on plants not affected with Leaf Roll. The rolled leaves of plants affected with this disease begin to die early. The harsh leathery texture of such leaves is a constant symptom. This point may be tested by feeling them with the fingers. The tubers of affected plants are small and are borne generally on very short tuber branches (stolons) or even attached in a cluster to the stem.

Cause—This is one of the virus diseases. Aphids or plant lice have been shown to be the chief carriers of the virus although it is probable that they are not the only carriers. The disease does not live over winter in the soil unless tubers that might produce volunteer plants are left in the field at digging time. Leaf Roll is transmitted chiefly through the "seed". Tubers from affected plants nearly always produce diseased plants.

Control—The most important means of control is the use of healthy "seed". The man who is growing potatoes for table stock can avoid serious loss from Leaf Roll by purchasing from time to time certified seed potatoes. Certified seed potatoes should be planted at some distance from other potatoes in order to prevent Leaf Roll being carried to them.

Other Important Virus Diseases

There are several other important "virus" or degeneration diseases in Ontario, chief among which are the potato Mosaics, which cause mottling and crinkling of the leaves and sometimes dwarfing of the plants. Spindly Tuber, which causes the tubers to become markedly elongated, off colour and in severe cases abnormally rough.

Plants affected by these virus diseases never recover. They are transmitted through the "seed". Tubers from affected plants produce diseased plants. In the field insects spread the infection. Plant lice (aphids) are chiefly responsible for spreading the various types of Mosaic.

Control—Use healthy "seed". Purchase from time to time certified seed potatoes and plant them at some distance from other potatoes to prevent these virus diseases being carried to them.

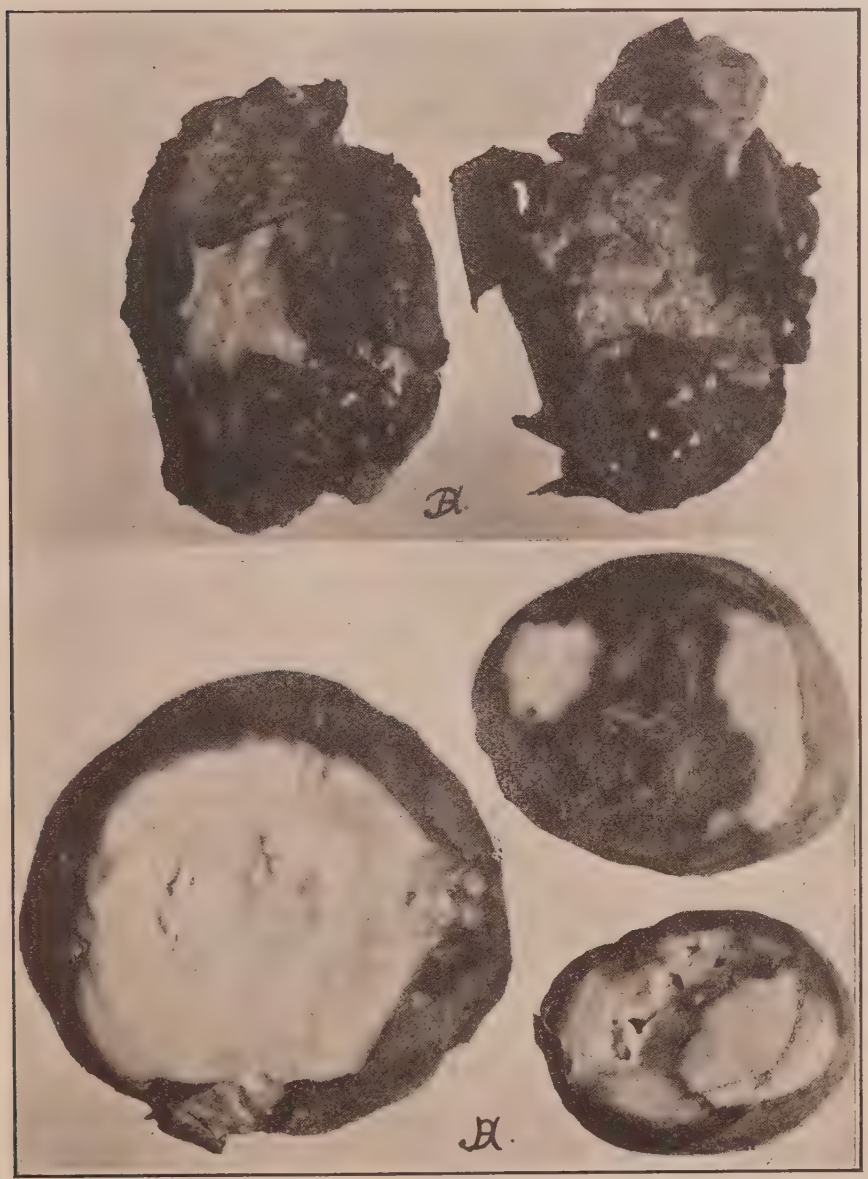
Potato Tubers, showing Bacterial Soft Rot in various stages of development, some tubers entirely rotted, others only partially affected.

1. Six tubers that contracted the disease directly through the stem from the parent plant.
2. Six tubers that contracted the disease at the eye and from coming in contact with other diseased tubers.

Blackleg, Basal Stem Rot or Bacterial Soft Rot of Potatoes

This disease is common and destructive in Ontario, and in wet seasons may cause very extensive losses in the potato crop.

Symptoms—The first symptom of the disease in those parts of the plant above the ground is a wilting or yellowing of the lower leaves. Later the upper leaves become yellow, reddish-yellow or even brown with an



Tubers in advanced stages of the Bacterial Soft Rot, taken directly from the field.

upward and inward rolling. There is also a tendency for the stems to grow erect instead of spreading out. The base of the stem from the seed piece to the surface of the ground, or even three or four inches above the ground in severe cases, will be found to be black. It is from this symptom that the disease derives its name Blackleg. The tubers are infected at the stem end first and may be partly or completely rotted. The disease is most destructive during warm, moist weather.

Cause—This disease is caused by the bacterial organism *Erwinia phytophthora* Appel. In most of the literature dealing with this disease the causal organism is given as E. atroseptica or E. phytophthora. The bacteria are carried over in the soil and on diseased tubers. The seed pieces are often infected by the seed corn maggot before planting. The maggot, contaminated with the organism from infested soil, or infected plant parts, carries to the seed pieces.

Control—Only certified seed potatoes from disease-free plants should be used. When a stock of seed potatoes has shown a small percentage of disease all those tubers having dark spots in the flesh should be discarded, and the remainder should be treated by immersing them, previous to cutting, for one and one-half hours in corrosive sublimate, one part to 1000 parts of water (one tablet to a pint of water), or in formalin one pint to thirty gallons of water. Decay during storage of potatoes may be checked by storing them dry, in well ventilated cellars, at about 38° F. Long rotation of crops is recommended, but as the causal organism infects nearly all vegetables this means using the field for such crops as sweet corn or other cereals, clovers and grasses.

Tip-Burn or Hopper-Burn of Potatoes

This trouble is very frequently seen in abundance in Ontario in hot dry summers. When serious it causes a marked reduction in the yield.

Symptoms—There is at first a slight wilting and rolling inwards of the edges of the leaves which soon turn brown. When the trouble is serious this browning and curling may extend to the midrib or near it over a considerable portion of the leaves.

Cause—There are two types of injury, (1) true tip-burn which is the result of hot sunshine and warm dry winds causing an excessive loss of water from the leaf tissue; (2) hopper-burn caused by apple leaf hoppers *(Empoasca mali)* puncturing the leaf veins and sucking the juice. This insect may often be seen rising in swarms as one walks through an infested field.

Control—Keep the soil rich in humus and see that the potatoes are repeatedly and thoroughly cultivated to conserve moisture. Spray with Bordeaux mixture as for Late Blight and Rot. Spraying has a direct effect on the true tip-burn as well as acting as a repellent for leaf hoppers.

TOMATOES

Late Blight or Leaf Spot of Tomato

This is the most common disease of field tomatoes in Ontario. In certain sections of the Province it causes serious loss to tomato growers by destroying the foliage early in the season, with the result that the fruit does not ripen properly or is sunscalded. It causes most damage in seasons of high temperature and high humidity.

Symptoms—Late Blight or Leaf Spot is easily recognized by the small, grayish-brown angular spots containing minute black specks which appear on the leaves and stems. Badly spotted leaves wither and dry up. The lower leaves are first affected and the disease spreads upwards, often completely destroying all the foliage of the plants except the new growth near the tips. Sometimes small spots occur on the fruit also.

Cause—The fungus which causes this disease is *Septoria lycopersici* Speg. This fungus produces countless spores in little black fruiting bodies (pycnidia) in the diseased spots on the leaves. During periods of high temperature and excessive humidity these spores are liberated and carried to other leaves or nearby plants by insects, wind, rain and the hands and clothing of pickers. This fungus is carried over the winter in the diseased leaves and stems, and in the remains of certain weeds which are also attacked by it.

Control—This disease frequently starts in the seed bed. In order to prevent this the following precautions should be taken. Any wood around the seed bed should be drenched with a solution of formalin (one pint to twenty gallons of water). If Leaf Spot has been prevalent in former years the soil in the seed bed should be renewed or sterilized with steam or formalin. (See directions on pages 64 to 68.)

Leaf Spot of Tomato. (Attacked leaves and stem).
(From Ohio Bulletin 73).

Experiments have been conducted for several years in spraying tomatoes in the seed bed only and spraying them both in the seed bed and in the field. The results of these experiments warrant spraying tomatoes only in the seed bed.

Directions for Spraying Tomatoes—Spray the plants in the seed bed when the first true leaves have appeared and again three or four days before they are taken to the field. Use a 2-4-40 Bordeaux mixture, adding three pounds Resin Fish Oil Soap to each 40 gallons. Water the plants well before spraying or as soon as the spray has dried on the leaves after spraying. Apply the spray at a pressure of 170 to 200 pounds. Do not hold the nozzle too close to the plants and do not overspray.

Some men prefer dusting although it does not give as much protection from diseases as spraying. Dust three times with a 20 per cent. copper lime dust, making the first application when the first true leaves have appeared and the other two at intervals of ten days. Do not allow large quantities of dust to fall on the plants as burning may result.

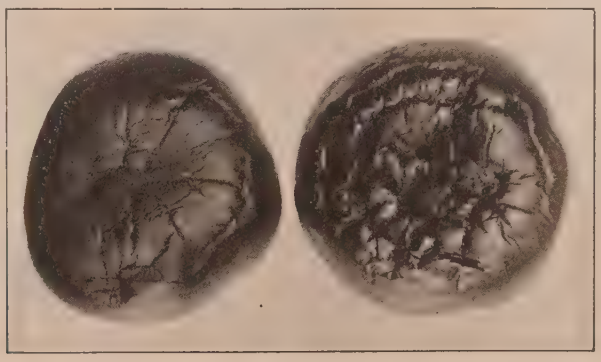
If Leaf Spot is very troublesome a rotation of crops should be followed so that tomatoes are not grown upon the same piece of ground oftener than once in three or four years. When such a rotation of crops is followed it is much easier to keep Leaf Spot under control.

Early Blight, Black Rot, Target Spot

This is a very common disease of tomatoes in Ontario. In wet seasons it causes very serious losses to the growers of canning tomatoes in Eastern Ontario.

Symptoms—On the fruits are seen dark brown or black sunken rotten spots. Some of these may be an inch in diameter. The discolourations from the rot usually extend to the centre of the fruit rendering it unfit for canning purposes. On the leaves may be observed somewhat circular, dark brown spots which are sometimes one-half an inch in diameter. They are readily recognized by the peculiar ring-like or target-like markings, hence the name "Target Spot". The spotting of the leaves is of comparatively little importance. It is the rot on the fruit that causes the loss.

Cause—The fungus *Macrosporium solani* E. & M. which causes Early Blight of potatoes is also responsible for this disease. The life history of this fungus is described under the cause of Early Blight of potatoes. (See page 38.)



Blossom End or Point Rot of Tomatoes. (Original).

Control—The directions given for the control of Leaf Spot of tomato apply also to the control of this disease.

Blossom End Rot of Tomatoes

This trouble is very common in Ontario both in tomatoes grown outdoors and under glass. It is most abundant outside in seasons when periods of hot dry weather alternate with those of heavy rainfalls.

Symptoms—The trouble appears usually when the first fruits are about half grown or a little later. Slightly sunken water-soaked areas are seen near the tip of the fruit. These are at first lead coloured or brownish but soon become lead-brown or black in colour and of a leathery texture. Various fungi and bacteria may gain entrance through these injured spots and cause rot which may destroy the whole fruit.

Cause—This disease is caused by unfavourable environmental conditions. Irregularities in the water supply and excessive nitrogen in the soil appear to be the two chief factors bringing about the development of this trouble.

Control—Avoid excessive applications of manure or other fertilizers which are high in nitrogen. Do not over force the plants, especially in the early stages of their development. Endeavour to maintain a state of even growth throughout the life of the plant. The water supply of tomatoes, grown under glass, should be even and regular. Outdoor tomatoes should be grown on well drained soil containing plenty of humus to retain moisture during dry weather. It is almost impossible to prevent this trouble on light, sandy soils lacking humus. In a dry period cultivation should be very shallow, just deep enough to fill any cracks that may appear, and to kill weeds. In wet weather the soil should be stirred enough to cause the excessive water to evaporate.

Tomato Mosaic

This disease is frequently seen in Ontario both in the field and under glass. It is not an uncommon thing to see fifty per cent. or more of the plants in a greenhouse affected by Mosaic.

Symptoms—There are two kinds of Mosaic of tomatoes, namely, Common Tomato Mosaic and Shoe String Mosaic. Plants affected with Common Tomato Mosaic have the leaves crinkled and mottled with yellow and green. Sometimes the yellow areas die and turn brown. Badly affected plants are dwarfed and usually set but a few fruits. Sometimes the fruit of diseased plants is russeted, streaked or blotched with raised areas.

The segments of the leaves on plants affected with Shoe String Mosaic are so narrow and slender as to appear almost thread-like.

Cause—Common Tomato Mosaic is caused by the same virus which affects tobacco and other closely related plants. This virus is spread by plant lice (aphids) and other sucking insects and by workmen, pruning and tying plants in the greenhouse or field. It will live in the soil for at least two months. It winters over in old tomato plants in the greenhouse and in the roots of perennial weeds which are closely related to the tomato, such as ground cherry *(Physalis spp.)*. There is considerable evidence to show that sometimes this virus may be carried over from season to season in the seed. It has been shown that it may live for a long time in tobacco, especially chewing tobacco, cigars and cigarettes. Workmen may, therefore, spread the disease by handling tomato plants when smoking or after

smoking if the hands are not thoroughly washed before handling tomatoes. They may also spread it to the seedlings in the seed bed by expectorating over them when chewing tobacco.

The Shoe String Mosaic is caused by the virus which affects the cucumber and closely related plants. It lives over the winter in the roots of the perennial weeds mentioned on page 24.

Control—All weeds belonging to the potato family, such as ground cherry, horse nettle, black nightshade, bittersweet and other related plants growing in the neighbourhood of the greenhouse, the seed bed and the tomato fields should be destroyed. All tomato refuse in the greenhouse and in and around the seed bed should be burned. The young tomato plants should not be placed in a greenhouse containing old plants. Since the virus can live in the soil the new crop of tomatoes should not be started in the seed bed or set in the greenhouse for at least four months after the crop has been removed. So far as possible control plant lice (aphids) by dusting, spraying or fumigation. In working among tomatoes the hands should be washed occasionally with soap and water and the pruning knife dipped repeatedly in formalin (one part in twenty parts of water). Breaking off the undesirable shoots in pruning permits less chance of infection than does cutting. Do not plant any of the following crops near tomatoes; potatoes, petunias, eggplants, peppers, cucumbers and other susceptible crops as the Mosaic may spread from them to tomatoes. Tobacco should never be used when working with tomatoes, especially cigars, cigarettes and chewing tobacco, and workmen who smoke should wash their hands thoroughly after smoking before handling tomato plants.

Streak or Winter Blight of Tomatoes

This is one of the most troublesome diseases of greenhouse tomatoes in Ontario. It often causes the loss of nearly the whole crop. It sometimes appears in the field but seldom causes severe loss.

Symptoms—The first indications of Streak are a rank sappy growth and the curling of the upper leaves and the younger portions of the stems and brown, sunken streaks or stripes on the young, vigorously growing stems. These streaks increase in width until the whole upper part of the stem may become brown. At first the browning appears to be on the surface only, but it soon becomes deeper seated and in bad cases involves the woody ring. About the time the first indication of streaks appear on the stem, brown angular spots appear on the leaves between the veins and these spots increase in size and number until the whole leaf is involved. Fruit sets very sparingly, often none on the first two or three trusses. The fruits that do set are commonly scabby, deformed and of poor flavour and colour. Large, soft, sappy plants are most subject to this disease. It is frequently accompanied by Mosaic.

Cause—Recent investigations in Canada and the United States have shown that Streak can be produced by a complex of viruses within the tissues of the tomato plant. A double inoculation with tomato mosaic virus and latent potato virus (mottle) or tomato mosaic virus and cucumber mosaic virus results in Streak, which can be transmitted in this form. Most investigators agree that Streak develops more rapidly and causes more serious losses in tomatoes which have been forced into too vigorous sappy growth by the use of fertilizers containing an excess of nitrogen. Any cultural practice which rapidly forces the plants into excessive growth appears to make them much more susceptible to Streak.

Control—Dr. R. E. Stone, of the Botanical Department, Ontario Agricultural College, has been carrying on investigations concerning the control of Streak for several years. As a result of these investigations he makes the following recommendations: Take all the precautions recommended for the control of Mosaic. Avoid the use of too much manure or other nitrogenous fertilizers such as ammonium sulphate or sodium nitrate. Be sure that the plants have plenty of phosphorus and potash. These elements may be supplied by using an 0-12-10 fertilizer at the rate of three to three and one-half pounds per 100 square feet of bed. This material should be worked into the soil before transplanting. If Streak appears apply acid phosphate, three ounces, and potassium sulphate, one-quarter ounce, as a side dressing to diseased plants. Avoid over-watering and irregular watering. Do not attempt to force plants that have been checked. Keep the plants growing evenly by maintaining a uniform temperature and watering regularly but not too heavily. Maintain a firm growth by providing good ventilation.

Leaf Mould

This disease frequently causes serious loss in greenhouse crops of tomatoes. It also occurs to a lesser degree in the field.

Symptoms—The leaves, especially the lower surface, become covered by an olive-brown mouldy or felt-like fungus growth. Affected leaves turn yellow or brown and in severe cases shrivel and die.

Cause—This disease is caused by the fungus *Cladosporium fulvum* Cke. This fungus is carried over from season to season in old diseased leaves in the soil of the greenhouse. It thrives best in a humid atmosphere and is very susceptible to temperature. The spores germinate best at a temperature of from 65° to 75° F. They will not germinate in a relatively dry atmosphere. Cloudy days increase the virulency of this organism.

Control—This Leaf Mould can develop only in almost completely saturated air. The management of the greenhouse, therefore, should be such as to keep the humidity too low for the growth of the fungus. Proper ventilation of the greenhouse is of prime importance. This can be accomplished by opening the ventilators and providing a little more heat if necessary. Some growers have found it profitable to instal electric fans of various types to keep the air in circulation. Space the plants far enough apart so that air can circulate freely amongst them and expose them to all the sunshine available. Wet the foliage of the plants as little as possible when watering, which is best done in the mornings of sunny days. If the Mould develops in cold weather lower the night temperature of the house to 55° F. for several nights in succession. In greenhouses, which are poorly lighted and poorly ventilated, spraying with Bordeaux mixture 4-8-40 may be of some value. Apply the Bordeaux heavily with high pressure at weekly intervals. Some growers recommend fumigating the house with sulphur. This is done by heating sulphur in porcelain dishes on electric heaters placed at regular intervals throughout the house. This fumigation with sulphur is done for a two-hour period just before the house is closed for the night and repeated at weekly intervals as long as there is danger from Mould. If fumigation with sulphur is attempted care must be taken not to get the sulphur hot enough to burn for it will then injure the tomato plants. Varieties of tomatoes resistant to Mould are being bred and it is hoped that they may soon be available to growers.

Leather End or Yellow End of Tomatoes

This disease occurs in all the tomato growing areas of Ontario but is particularly troublesome in the Eastern Ontario district which includes parts of Durham, Northumberland, Hastings and Lennox and Addington counties and all of Prince Edward. It attacks both field-grown and greenhouse tomatoes although in the case of the latter it usually appears only in the spring crop. All of our commonly grown varieties are susceptible but some, especially those of the Earliana type, are much more so than others. This disease may cause some loss to growers of greenhouse and early market tomatoes, but it is most serious in canning tomatoes. In seasons favourable to the development of the disease, as much as fifty per cent. of the canning crop may be affected while in other years only five or six per cent. is diseased. The loss to the grower comes as a result of having the grade of his tomatoes considerably lowered or having a certain per cent. docked on account of the presence of diseased fruits. The canner also suffers loss since the diseased portions, which cannot be processed, have to be cut away and a great deal of wastage results. When the diseased portion is cut away the seed locules are usually opened so that there is considerable loss in addition to the part actually removed.

Symptoms—This disease may be recognized by the failure of the stem end of the fruit to ripen properly. Instead of becoming red ripe like the rest of the fruit, the area around the stem remains a greenish yellow, yellow or bronze in colour and is quite hard and leathery in texture. Sometimes almost a third of the fruit is involved and the diseased portion never ripens no matter how long the fruit is left on the vine. Only the wall of the fruit is involved and the inside of the tomato in the diseased portion may be quite normal.

Cause—Leather End is a disease caused by faulty environment. The exact causal factor has not been determined, but experiments have indicated that exposure to sunlight combined with high temperatures are favourable to the development of the disease. Defoliation increases the amount of disease, and shading, even when the foliage is removed, gives almost one hundred per cent. control. Any other factor such as moisture supply, soil fertility, etc., which influences the amount of vine growth will in turn have an effect on the amount of disease. Poor vine growth is always associated with severe attacks of Leather End. This probably accounts for the disease being worse on sandy soils since the vine growth in such soils is usually less than where the soil is heavier.

Control—Leather End may be greatly reduced by having the land on which the tomatoes are grown in a good state of fertility with an ample supply of organic matter, and by giving in addition an application of a complete fertilizer, carrying at least six per cent. of potash and on lighter soils ten per cent. of potash. If the humus content of the soil is low the fertilizer should contain at least four per cent. of nitrogen but this element is best supplied by decaying organic material. The following suggestions are made regarding the use of commercial fertilizers in the control of this trouble: On loam to clay-loam soils use a 2-12-6 analysis at the rate of 500 to 700 pounds per acre, and on sandy loam to sandy soils use a 2-12-10 analysis at the same rate. In either cases, if there has been no legume crop, such as clover, sweet clover or alfalfa preceding the tomatoes, a side dressing of nitrate of soda or ammonium sulphate at the rate of 200 pounds per acre should be given in addition to the complete fertilizer. This side dressing may be given about two weeks after the plants are set out into

the field. Ultimate success in the control of this disease depends upon ample vine growth for the protection of the fruit. In addition to the above recommendations, open growing varieties such as Earliana should be avoided in areas where Leather End is prevalent.

Bacterial Canker of Tomatoes

This disease is sometimes found in Ontario but so far has not caused any serious loss, though a number of enquiries have been received concerning it.

Symptoms—The chief symptoms of this disease are seldom observed until the plants begin to blossom. About this time there is a wilting, rolling, and browning of the leaves on one side of the plant. These symptoms are followed by the appearance on the stems of yellowish-white streaks, which later become grey-brown, and crack open, forming cankers. From these cankers bacteria emerge to the outer surface. In extreme cases the pith of the stem collapses and becomes discoloured. The disease extends rapidly up the stem, and if the fruit is set it becomes stunted and distorted. There is a yellow to brown discolouration of the inside of the fruit, and also irregular somewhat sunken spots on the exterior. This disease differs from the Fusarium Wilt in that it does not cause sudden wilting of the entire plant.

Cause—This disease is caused by the bacterial organism *Phytomonas michiganense* (E. F. Smith), Bergey et al. The bacteria winter over on the seed and in old diseased plant refuse. They may enter the plant through the breathing pores (stomata), but usually infection is through the food and water conducting vessels of the plant.

Tomato vine affected with Bacterial Canker.

Bacterial Canker spots on tomato fruit. (After Chupp).

Bacterial Soft Rot of Cauliflower and Cabbage.

1. Bacterial soft rot of cauliflower, natural infection; specimen taken direct from garden.
2. *Erw. caratovora*, the vegetable soft rot bacillus seen between cells of broken-down, rotting cauliflower. (x 1000 di.)
3. Bacterial soft rot of cabbage. Artificial stab inoculation of a pure culture of *Erw. caratovora* in healthy cabbage. Photo taken twenty days after inoculation.

Control—Care should be taken to select seed from healthy plants. Seed may be treated by tying it loosely in a cheesecloth bag and submerging it in corrosive sublimate, one part to 3000 parts of water (one tablet to three pints of water) for five minutes, after which it should be washed in clear water. If this disease becomes troublesome crop rotation should be followed so that tomatoes are not grown on the same land more than once in three or four years. Tomato refuse should be ploughed in deeply or destroyed.

Bacterial Soft Rot of Vegetables

This disease affects many fleshy vegetables and flowers, especially turnips, cauliflowers, potatoes, carrots, cabbages, celery, tomatoes, German iris and calla lily, and to a lesser extent, onions, asparagus, salsify, sugar beet, mangel, muskmelons and others.

Symptoms—It would require a very lengthy discussion to deal with minor symptoms as they occur in the various plants, and this is considered unnecessary since the general symptoms serve to identify the disease.

The organism causes a progressive soft, wet rot of affected roots, rhizomes, fruits, fleshy stems and leaves of vegetables and other plants. The rotted portion varies in colour from reddish-brown to dark brown or black in the case of affected green tissues. There is a clear line of demarkation between the healthy tissue and the diseased tissue. This is explained by the fact that, as the organism multiplies it produces digestive enzymes, which act upon the healthy tissue making it soluble and available as food for the bacteria. The middle lamella or the cementing material which holds the cells together to form vegetable tissue, is first attacked so that the cells collapse. This results in a soft rotten mass, dark in colour, with an offensive odour. When the disease occurs in the cauliflower it most commonly affects the head, but may also affect the leaves and stem. The usual discolouration and rot of the head soon becomes noticeable. In the turnip, the rot usually starts at a wound near the crown, and progresses through the root.

Cause—This disease is now known to be caused by the bacterial organism *Erwinia caratovora* (Jones) Holland. It is incapable of penetrating sound tissue, and is introduced into the plant on the mouth parts of insects which have previously fed on diseased plants, or it may gain entrance through wounds caused during cultivation and handling of the plants.

Control—Spraying with insecticides is beneficial indirectly since it helps to keep down insects, but spraying with fungicides is of little or no avail. When storing vegetables, only those free from any indication of disease should be kept. Before storing, the vegetable house should be washed or sprayed with formaldehyde, one pint in ten gallons of water, or copper sulphate one pound in five gallons of water. Good ventilation should be supplied and a temperature a little above 32° F. maintained, but freezing should be avoided since tissues weakened by freezing may be attacked by other bacteria. Long rotations with immune crops such as corn, cereals and grasses are recommended. Applications of lime and superphosphate are said to reduce the severity of this disease.

Damping Off

The seedlings of many plants are liable to be affected by this trouble. It occurs mostly in the seed bed where plants are growing in a crowded

Bacterial Soft Rot of Turnip.

1. Turnips direct from field badly affected with bacterial soft rot. Shaded areas were soft, pulpy and strong smelling. Evidently inoculated near the crown, probably through wounds made by slugs or caterpillars or during cultivation.

2. Soft-rotting turnips direct from field, in which the disease had been prevalent the previous year. These had evidently been inoculated from the soil through wounds made while hoeing or cultivating.

condition. It is seldom found in the open field. It is also a common disease in greenhouses where relatively high humidity is maintained and where the plants are not exposed to sunshine and free circulation of air.

Symptoms—The stems near the ground are girdled by brown lesions which cause the plants to fall over and ultimately die.

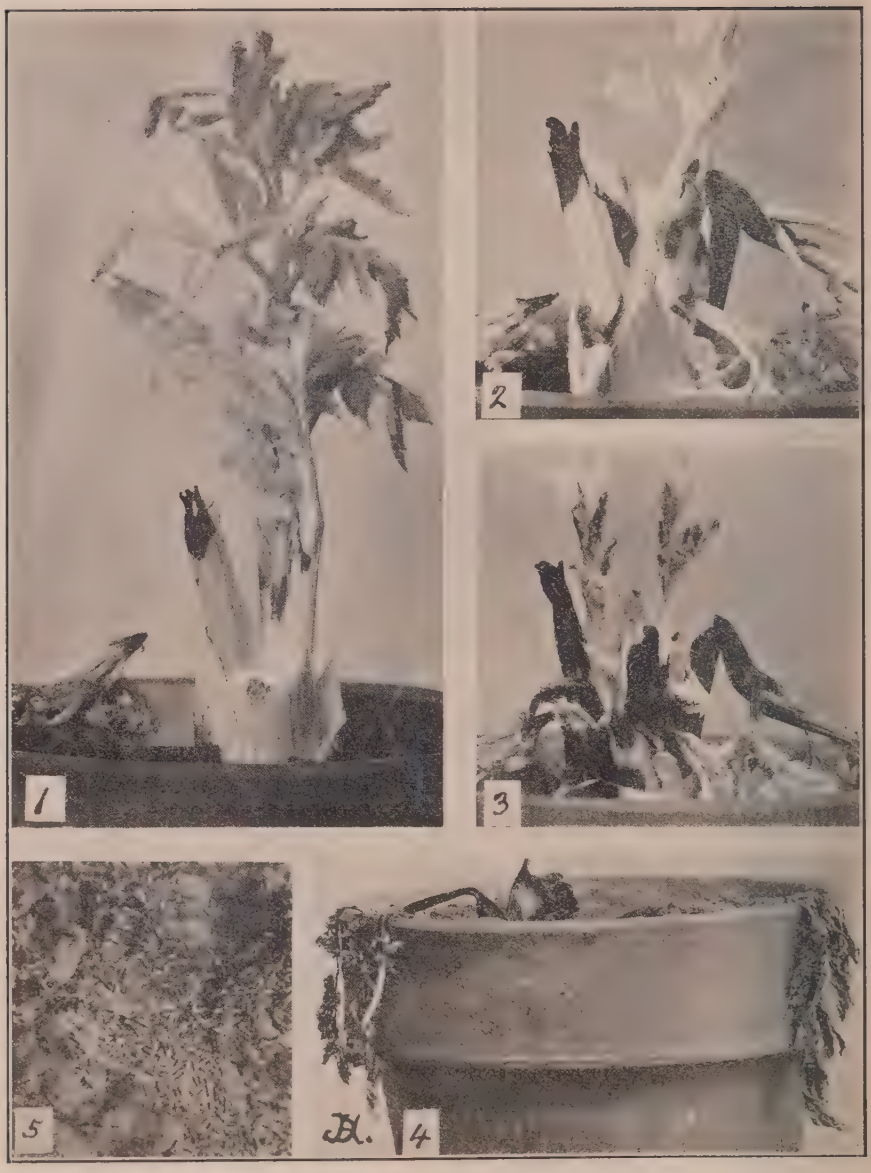
Cause—Rhizoctonia, species of Fusarium and Pythium are the fungi causing most of this trouble.

Control—If serious Damping Off has occurred at some time, the soil should not be used again or, if used, it should be sterilized with steam or formalin (see page 64). In order to prevent the accumulation of too much moisture in the surface soil and to reduce the humidity of the air about the plants: (1) sow the seed in rows and not too thickly; (2) sprinkle a layer of coarse, dry sand over the surface of the soil; (3) stir the upper layers of the soil frequently; (4) in cool, damp, cloudy weather ventilate freely and supply plenty of heat if possible; (5) water the plants in the morning rather than in the late afternoon or evening; (6) avoid overwatering.

Proper seed treatment often does much to increase stands and control Damping Off. Treated seed may be stored for short periods of time without injury but it is preferable to apply the treatment just as the seed is required. There are various mercuric compounds on the market that many growers are using successfully for treating seed. These compounds should always be applied according to the directions on the container. Red Copper Oxide has been found satisfactory for the prevention of Damping Off in many crops. The method of application is to place the seed and the dust in a closed container and shake the container vigorously for two or three minutes so that every seed will be coated with the dust. In order to allow the seed and the dust to mix properly the container should not be more than half filled. A pint or quart glass sealer is very satisfactory for treating small quantities of seed. Packet seeds may be treated in the packets. The following rates of application are suggested: One level teaspoonful per pound of seed for seeds the size of spinach or smaller and for light seed like beets or chard, and one teaspoonful per ten pounds for larger and heavier seeds like peas, squash and cucumber. Any excess of dust should be screened out before the seed is sown.

Caution—Red Copper Oxide should not be used on the seeds of plants belonging to the mustard family, such as cabbage and cauliflower.

Treating the seed will prevent it from rotting and afford protection to the young plants from fungus attack before they emerge from the soil. It will not, however, effectively prevent Damping Off after the seedlings are up for two or three days. If Damping Off develops in the seed beds at this time there are two treatments that will check it. The first treatment consists of the use of Zinc Oxide which is sold commercially under the name of Zinc White and is used for making zinc paints. It is used at the rate of about one-half ounce per square foot of soil and is sprinkled on the dry plants in the afternoon or on a cloudy day and then brushed off onto the soil. Sufficient material should be applied to give a smooth white layer over the soil. This layer should be left in contact with the plants until the danger of Damping Off is past. Water carefully so as to disturb the layer as little as possible. The second treatment is the use of Red Copper Oxide in the form of a spray. The Red Copper Oxide is used at the rate of one pound in forty gallons of water and is sprayed on the young plants so that



Bacterial Soft Rot of Celery.

1. Artificial needle inoculation of pure culture of *Erw. caratovora* (isolated from rotting cauliflower) into the young and vigorous growth of celery. Five days after inoculation, kept at 25° C.
2. Same as Fig. 1, five days later.
3. Same as Fig. 1, ten days later.
4. Same as Fig. 1, three weeks after inoculation, showing complete collapse of plant.
5. E. carotovorous, the vegetable soft rot bacillus, between the cells of rotting celery tissue (x 1000 di.).

it will run down the stems to the soil level and also wet the surface of the soil. If Damping Off is feared the surface of the soil may be sprayed before the seedlings emerge. This treatment is less expensive and easier to apply than the Zinc Oxide.

FUNGICIDES

Bordeaux Mixture

This is almost the only spray used on vegetables for the prevention of fungus diseases. The two formulae recommended for the preparation of Bordeaux mixture for spraying vegetables are: (1) Bluestone (copper sulphate) four pounds, hydrated lime five pounds or fresh stone lime four pounds and water forty gallons; (2) Bluestone three pounds, hydrated lime four pounds or fresh stone lime three pounds and water forty gallons. Hydrated lime is the more convenient form to use as it does not require slaking. It can be purchased in fifty-pound paper sacks and is easily stored. If left exposed to the air, however, it becomes worthless, so keep it in tightly fastened paper bags in a dry place.

To prepare Bordeaux Mixture:—Dissolve the bluestone, then nearly fill the tank with water. Add the proper amount of dissolved bluestone. Then while the engine is running add the hydrated lime or slaked stone lime and agitate the mixture for about five minutes. If a hand outfit is used put end of the hose in the tank and agitate by pumping the liquid back upon itself for five minutes.

N.B.—The easiest way to dissolve bluestone in the crystal or lump form is to place forty pounds of it in a bag and suspend this in a barrel containing forty gallons of water, in such a way that the bottom of the bag sinks only three or four inches below the surface of the water. Leave over night and in the morning all will be dissolved. One gallon of the liquid will now contain one pound of bluestone. Small quantities can be dissolved readily by stirring in boiling water. Granulated bluestone dissolves very readily. If the desired amount is placed on a burlap screen over the opening in the tank it will dissolve while the water passes through it to fill the tank.

Copper Lime Dust

(Bordeaux Dust)

Some growers prefer to use this dust instead of the liquid Bordeaux. It is made of very finely ground bluestone (copper sulphate) and the best grade of chemical hydrated lime. Calcium arsenate is sometimes added for a poison. The formulae most generally used are: (1) twenty pounds bluestone and eighty pounds lime; (2) twenty pounds bluestone, sixty pounds lime and twenty pounds calcium arsenate. The best results from dust have been obtained by applying it liberally with a high-powered duster when the plants were wet with rain or dew.

Resin Fish Oil Soap

Resin Fish Oil Soap is used with Bordeaux when a sticker is required to make the fungicide adhere better to the foliage. Three pounds of the soap are used with each forty gallons of the Bordeaux. The soap is first mixed with water, using one gallon of water for each pound of soap. Hot water is preferable to cold water.

Formalin

Formalin is a clear liquid disinfectant. It is a 40 per cent. solution of formaldehyde gas in water. It is sold under the name of formalin and formaldehyde. It can be purchased in a drug store by the pound (sixteen ounces) or by the pint (twenty ounces). It is important that the purchaser secures a solution of full strength at least not less than thirty-eight per cent. The solution should be kept in a well-corked container and away from the frost. Formalin when diluted with water is not a dangerous poison, although a weak solution will make the eyes smart and a strong solution will harden the skin temporarily.

Corrosive Sublimate (Mercuric Chloride)

Corrosive sublimate may be obtained from any druggist. This is a deadly poison and should be so labeled and kept out of the way of children and stock. It is sold as a powder or in the form of tablets, one of which dissolved in a pint of water gives a solution of the strength of one part by weight of corrosive sublimate to 1,000 of water. It is not readily soluble and hot water should be used to dissolve it. It corrodes metal and therefore should be mixed in wooden or earthen vessels. It is an excellent disinfectant but even in dilute solutions it is deadly poisonous. Great care therefore must be used in handling it. Potatoes disinfected with it should never be used as food for man or beast, and vessels which have contained it should be thoroughly washed with hot water before they are used for any other purpose.

Soil Sterilization

Many destructive insect and disease pests live over from crop to crop in the soil, particularly in greenhouses. In order to get rid of these, soil sterilization becomes an important factor in the production of greenhouse crops. Care is required during the sterilizing to see that all parts are thoroughly done and also afterwards, to see that the soil is not reinfected by other soil brought in from another house on contaminated boots or dirty tools. If the soil becomes contaminated just after sterilizing, the disease usually develops more rapidly than it would if no sterilizing had been done.

There are two methods of sterilizing soil, one by using formaldehyde or other soil disinfectants, and the other by using steam. The steaming is preferable as it is more thorough, gives better control of nematodes and plant diseases and kills the weed seeds present. Steaming may also improve the condition of the soil by liberating certain salts that were in the ground but were not in an available form for the plant. In rare cases, however, the crop following steaming is poorer than that previous to steaming as toxic substances which are harmful to growing crops may be liberated during the steaming. All seed beds and greenhouses are not equipped for sterilizing with steam and hence formaldehyde or some other disinfectant must be used.

The term sterilization as used in this bulletin is synonymous with disinfection.

Formalin or Formaldehyde

Use one pint of formaldehyde to ten gallons of water and by means of an ordinary sprinkling can apply this solution at the rate of one gallon to one square foot of soil. If the soil will not absorb one gallon per square

foot make the solution stronger so as to get a pint of formalin on about ten square feet. It may be necessary to use a pint of formalin to six gallons of water and then add the six gallons to ten square feet of soil.

Dig up the soil before treating and as soon as sufficiently dry after treating dig up again. Do not set out any plants or sow any seeds for at least ten days after treating and if not good drying weather leave longer. If the soil is light and likely to dry out quickly it is advisable to cover it for a day or two after treating, using tarpaulin, heavy paper or some such material suitable for this purpose. Formalin, like many other chemical substances, will not control nematodes.

Steam

Sterilizing the soil with steam is the best method that can be used. As stated above, it not only destroys insects and disease organisms but it also kills weed seeds. The soil should be in a loose condition with no large lumps when steamed. It should not be too wet as it requires much more heat to raise the temperature of wet soil. Soil that is a little too dry for good plant growth is usually in a good state for sterilizing. The water holding capacity of the soil may be changed somewhat during steaming, hence for some time after steaming it may be necessary to use more water at a time and water more frequently. Various methods are used in steaming the soil, some of which are as follows:

1. Inverted Pan. For outside seed beds or for small greenhouses where there are no posts and where nematodes are not giving trouble this method gives good results. If posts are in the way, the soil around them cannot be sterilized in a satisfactory manner and contamination of what has been sterilized soon takes place. When nematodes are present those near the surface may be destroyed but many deeper in the soil will remain.

A pan 6 feet x 12 feet and 8 inches deep made of No. 16 galvanized iron reinforced with angle iron is a convenient size of pan to use. In order to move the pan a handle or large ring should be attached to each corner of it. The pan should be held in place by stones or bags of sand and the soil banked around its edges. The steam should enter in such a manner that it is not forced directly into the soil at the point of entrance. The steam may enter at the central part of the pan and a "T" fitted on the inside so as to force the steam each way, or the steam may enter at one end of the pan, or a bent pipe may be used which will pass underneath the edge of the pan and the open end come above the surface of the soil underneath the pan. The pan is connected to the boiler by means of piping and heavy rubber hose. The boiler should have a capacity sufficient to discharge steam at 80 to 100 pounds pressure and the pan left in position for thirty minutes or longer. As a thermometer cannot be used while steaming to determine the temperature of the soil some other means may be used as a check. The old method of cooking a potato placed about four inches below the surface of the soil may be tried. When the pan is moved forward to a new position it should be placed so that it will slightly overlap the area already sterilized. It is advisable to cover the place that has been sterilized with tarpaulin or canvas for some time in order to retain the heat and secure better penetration. Care must also be taken when moving the pan that no dirt be carried from the unsterilized area to that which has been sterilized. A threshing engine that is in good condition may be used for sterilizing with the pan system.

2. STEAM HARROW. The steam harrow is shaped somewhat like an ordinary field harrow. It is composed of hollow iron cross pieces and hollow teeth about eight inches in length. At the lower end of each tooth is a small hole to allow the steam to escape. The whole harrow is covered with a heavy canvas so as to prevent the escape of steam. The teeth are forced to their full depth into the soil and the steam is passed into the cross bars from an attached pipe and escapes at the point of the teeth. As most of the steam escapes up the side of the teeth and does not penetrate the soil to any great extent, the steam harrow gives no better results than the inverted pan, hence this method has been discarded.

3. STEAM PIPES. A number of pipes having a diameter of 1½ or 2 inches are used. A row of holes ⅛″ diamenter and 1″ apart is drilled along one or both sides. These pipes are placed in the soil in parallel trenches about 18″ apart, one end connected with a cross pipe which is joined to the steam line. The trenches are then filled in and steam passed through the pipes. This method, however, is not very satisfactory as the trenches have to be dug and the pipes changed before and after each steaming. The pipes may be left in the soil, but if this is done the holes are likely to become plugged and the pipes rusted.

4. TILE. In the larger greenhouses and where nematodes cause trouble, steaming through tile is the most satisfactory method of soil sterilization. The steaming should be done during the summer months as there is a much greater saving of fuel than when done during the winter months. It is also advisable to cover the area that is being steamed with tarpaulin, heavy paper or even bags or sacks in order that the steam may be held longer in the surface of the soil and not pass off so freely into the air. Such covering is required particularly during the winter months, otherwise it takes much longer to heat the surface of the soil.

Laying the Tile—Parallel trenches are dug and 3 or 4 inch tile are laid so that the top of the tile will be about 12 to 15 inches below the surface of the soil. They should be deep enough so that when the soil is being dug up there is no danger of breaking the tile. In some light open soils where nematodes are bad it may be advisable to place the tile a little deeper. The middle of the trenches may be from 18 inches to 2 feet apart, depending on the nature of the soil. If the soil is loose and open the tile may be placed deeper and a little farther apart than in soil of a heavier type. It is not advisable to have tile more than 2 feet apart in any soil. The ends of the tile should not be fitted together too closely, but left a short distance apart in order that the steam is free to escape at all joints. Small thin pieces of wood such as material used for making fruit baskets might be put between the tile to make sure they are not fitted too closely. A small amount of crushed stone or coarse gravel may be added at the joints as this will also assist in allowing the free escape of steam. If the tile are laid lengthwise in the greenhouse the outer rows should be laid close to the side walls and the ends of the rows should come close to the end walls, or a row of tile may be laid between the ends of the rows and the end wall of the greenhouse. It frequently happens that the soil around the walls or along the walks is not thoroughly sterilized.

Length of Rows—The length of the rows of tile depends to some extent on the capacity of the boiler to be used in steaming. Tile may be laid the length of the house and steam passed into one or two or more rows at a time. By fitting a "T" into the middle of a long row of tile the steam may enter through it and pass each way. Where a large boiler has been

used satisfactory results have been obtained in houses 300 feet long, two rows of tile being steamed at the same time. The steam entered at the middle of the row and passed 150 feet each way. When long rows of tile are used, the end farthest from the entrance of the steam should be fitted with a small pipe coming to the surface of the soil. This should be left open until the steam begins to escape freely, and then closed. This is particularly necessary in heavier types of soil in order to allow the cold air in the tile to escape and thus ensure a more even distribution of steam. In loose, open soils the cold air in the tile escapes more easily, hence it is not so necessary to have the far end of the tile fitted with a small pipe.

Although long rows of tile may be used, one end frequently heats up faster than the other, hence a loss of steam or a broken tile in the line will give trouble and will have to be replaced before the steaming can be completed. For these reasons it is preferable to have a number of short rows of tile coupled up in such a manner that the steam entering at one place can flow into the whole block at once. Thus in place of passing steam into one row of tile 300 feet long better results are obtained by passing steam into 10 rows each 30 feet long. If this system is followed a row of tile should be laid crosswise at both end of the rows and coupled up with the ends of each row. When steam enters this block of tile it will circulate throughout the whole block in a short time as it can enter freely at either end of the rows of tile. If there is a broken tile in any row the steam can enter at the other end of the row.

Steam Line to Tile—The tile may be connected to the steam line in different ways. By means of an elbow and two short pieces of 2-inch pipe an "L" shaped piece may be put together. One end of this is placed in the tile and the other end above the surface of the soil. A cap may be screwed on this end to keep the dirt out when not in use. If the steam is to enter at the middle of a long row then in place of an "L" a "T" may be used. Steam may be carried from the boiler to the tile through pipes used for heating, but it is much more satisfactory to run a direct line from the boiler using a 2 or 2½-inch pipe. The pipe may be connected with the piping in the soil by means of a jackknife structure and an ordinary union or by using a piece of heavy rubber hose.

Steaming—When starting to steam one should have on hand one or two good thermometers that will stand a temperature of over 212° F. (boiling point) and protected by a case so that they can be inserted in the soil. Such thermometers are expensive, but are necessary if one is to be sure of a thorough job and at the same time not waste time and fuel. A good dairy thermometer may be used, but it is not very satisfactory. The length of time required to sterilize any soil depends on the capacity of the boiler and the area that is being sterilized. The larger the area the longer it will take. One thousand square feet may be sterilized by a 100 H.P. boiler, but it will require a longer time than if a smaller area is being done.

Most of the organisms causing plant diseases are killed by steaming in a fairly short time, but a few such as fusarium wilt of tomatoes and nematodes are more difficult to control. If the tile have been properly laid and steam is escaping at all the joints the results ought to be satisfactory if steaming is continued for 30 minutes after the temperature of the soil between the rows of tiles has reached 200° F. Sometimes it is advisable to continue the steaming for an hour as there are often spots where the steam has not penetrated as rapidly as it has in most of the soil. When

the steam is shut off an opening should be left so that air can pass freely into the tile. If the opening is closed a suction develops as the steam within the tile condenses and this may cause wet soil or mud to be drawn into the tile.

Potting Soil—It is advisable to steam soil that is to be used for potting purposes as this kills insects, weed seeds and fungi that frequently cause "damping off" of plants when they are small. The soil may be sterilized either by the inverted pan or by tile or by building a box with pipes fitted on the bottom or lower part of the sides. On one side of the pipes there should be holes about $\frac{1}{8}$ inch in diameter and about 6 or 8 inches apart. The box is filled with soil, a tight-fitting lid put on and steam passed through the pipes. By using the box a more thorough job can be done and contamination is less likely to occur than with the other methods.

ACKNOWLEDGMENT

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